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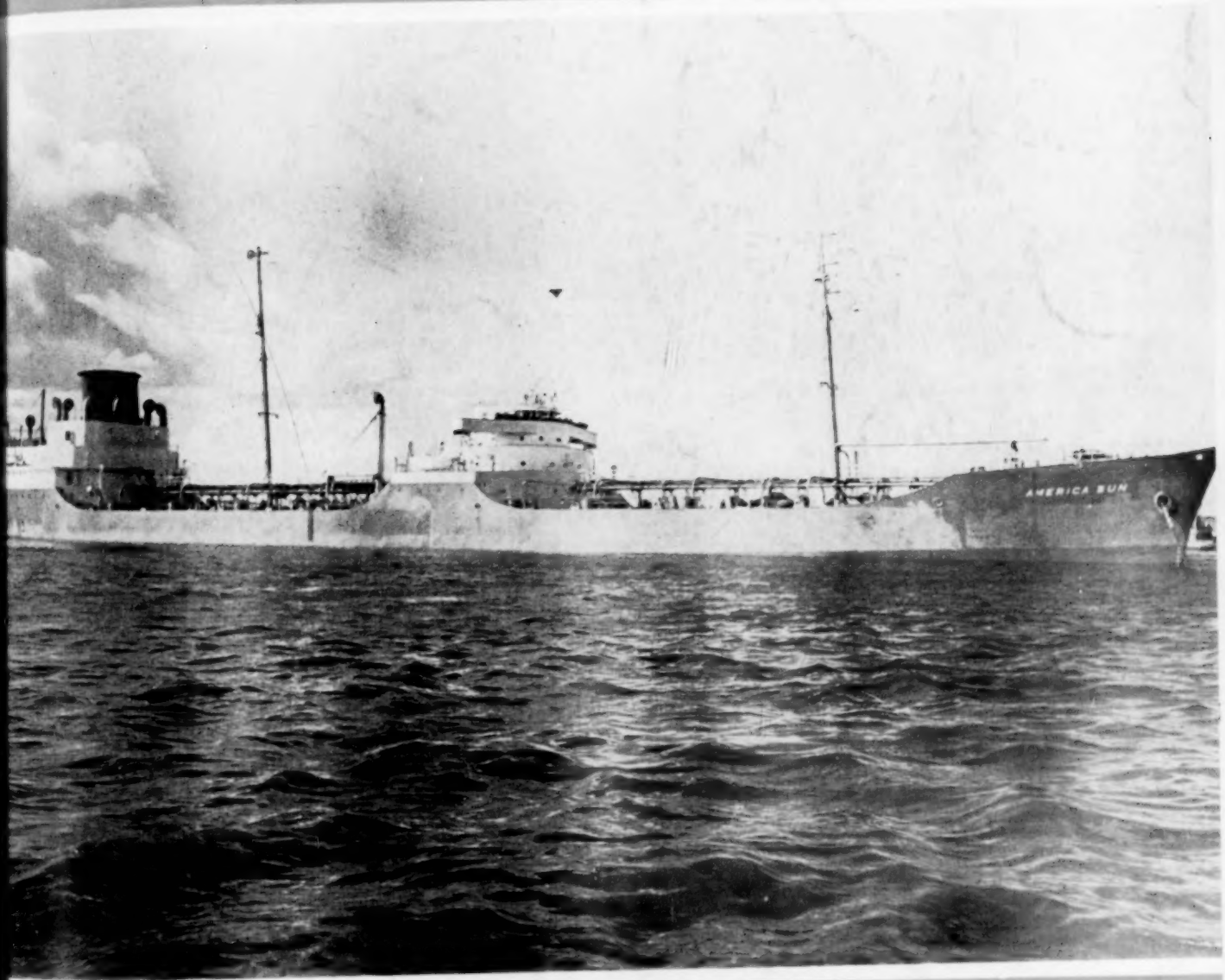

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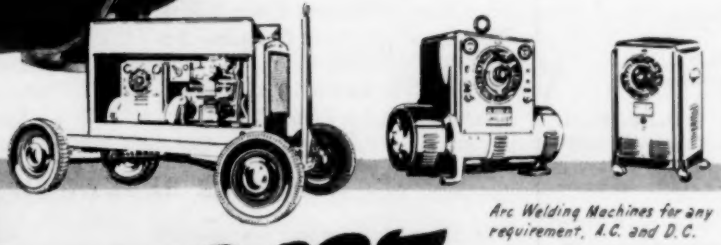

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Published for the Advancement of the Science and Art of Welding

W. SPRARAGEN, Editor

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CONTENTS

TECHNICAL PAPERS, ITEMS AND REPORTS

Helium-Shielded Arc Welding of Stainless Steel Exhaust Collectors, by Francis H. Stevenson 873
Arc Welding Practice in the Steel Foundry, by Frank Kiper and Lawrence Gabes 877
Small Portable Condenser Welding Set, by E. M. Callender 882
Routine Inspection and Salvage of Machinery Weldments, by James W. Owens 891
Current Welding Literature 905
Evolution of Welding in Shipbuilding, by M. N. Maltseff 906
Low-Reactance Cables for Portable Resistance Welders, by Myron Zucker 911
Standard Details for Welded Building Construction, by H. W. Lawson 916
Fundamentals of Heavy Cutting, by G. L. Walker and H. G. Hughey 934
American Bureau of Shipping Meeting 942

SOCIETY AND RELATED ACTIVITIES

A.W.S. to Hold 25th Annual Meeting 944
Rules for Fusion Welding Piping in Marine Construction 944
Adam's Lecture—A. B. Kinzel 944
Stanley to Receive A.S.M. Research Medal 944
Index to Advertisers 946
Newly Elected Officers 950
Directors-at-Large 954
District Vice-Presidents 958
Sustaining Company 968
Sustaining Member 968
Metals Society to Receive Ordnance Award 968
Welding Distributors Association 968
Resistance Welding Units from the Consumer's Point of View 968
Booklet on Underwater Cutting and Welding 970
Free Flowing Solder for Aluminum 970
G. A. Ostrom Moves to Foote Mineral 970
The Champion Rivet Company Appoints N. J. Carbis 970
Pressure Shock Equalizing Valve 970
Wartime "Double Ring" Ceremony 972
Tractor Repairs 972
Battelle to Receive Distinguished Ordnance Award 972
Rebuilding Worn Valves 972
Extending the Life of Tools and Gages 972
Welding Chart 976
Frostrode Products Moves Into Larger Plant 976
California State Department of Education 976
Streamlined Refinements in Industrial Application of X-Ray Units 976
Machinery and Welder Corporation Building 976
New Products 978
Section Activities 982
Employment Service Bulletin 984
List of New Members 984
Members Reclassified 988
Sustaining Member 988
Sustaining Companies 988
Sections—Chairmen, Secretaries, and Regular Meeting Dates 990
Welding Codes, Standards and Specifications 998

WELDING RESEARCH SUPPLEMENT

The Effect of Time and Temperature on Relief of Residual Stresses in Low-Alloy Steels, by J. K. McDowell and Lt. Col. Paul C. Cunnick 481-s
Characteristics of Welding Arcs on Aluminum in Atmospheres of Helium and Argon, by F. A. Wassell 487-s
The Geometry of a Spot-Welding Tip and Its Relation to Tip Life, by Earl D. Crawford and C. W. Steward 494-s
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Helium-Shielded Arc Welding of Stainless Steel Exhaust Collectors*

By Francis H. Stevenson†

THE 18–8 type of stainless steel is used almost exclusively in the manufacture of exhaust collectors. Let us review very briefly two of the points which cause the welder and user of this steel difficulty:

1. Carbide precipitation.
2. Distortion.

How can we control the above two points?

The carbide precipitation can be controlled, first, by the addition of stabilizing elements such as columbium or titanium. However, even with the addition of these elements, some precipitation still occurs. Second, it can be controlled by the length of time which the steel is under the welding heat.

The distortion can be controlled, first, by the use of suitable welding fixtures; second, by the length of time the part is under the welding heat.

It was this time element which led our company to start experimenting with this process in the early part of 1943. In our Dept. 17-04, at Factory A-2, we were fabricating some experimental stainless steel heat exchangers. The material was relatively thin and during the fabrication of these parts, by the oxyacetylene process, considerable distortion was encountered. It was then decided to use the helium-shielded arc process. We found that distortion was very slight and our welding time considerably reduced.

Figure 1 shows a section of the heat exchanger. The plate is the Type 347 stainless steel 0.042 in. in thickness, as are the tubes; holes are punched and flanged in the plate with tubes inserted and a standing-edge weld is then made without the use of flux. Inasmuch as we had considerable success in fabricating the heat exchangers by this process, it was decided to investigate the process further to find out its production possibilities in the manufacture of our exhaust collector. Further in the paper we will discuss some of the laboratory tests.

This process is quite similar to the oxyacetylene in manipulation of the torch and rod in that the arc surrounded by the helium blanket may be likened to the oxyacetylene flame, the material being added from an outside source being common to both processes. In fact, we have found that a good oxyacetylene welder is more easily adapted to the process than a metallic arc welder, probably because of the similarity of the welding technique of the two processes. The same Army welders' qualification test is required for this process, as when qualifying a welder on the oxyacetylene process of welding stainless steel. We use a commercial helium of 98% purity which can be supplied by any of the well-known gas manufacturers. The arc machines we use are 150-amp. d.-c. generators of standard manufacture. The helium-shielded arc-welding process makes use of an electric arc applied to the metal being welded through a tungsten or carbon electrode. In the welding of stainless steel a carbon electrode is used with straight-polarity; electrode negative, work positive. Helium gas is allowed to flow through the torch, around the electrode and on to the molten metal, thus shielding the arc and molten metal from the atmosphere which in turn prevents oxidation. Helium is an inert gas and will not unite in any way with the elements of the molten weld puddle to form a new compound.

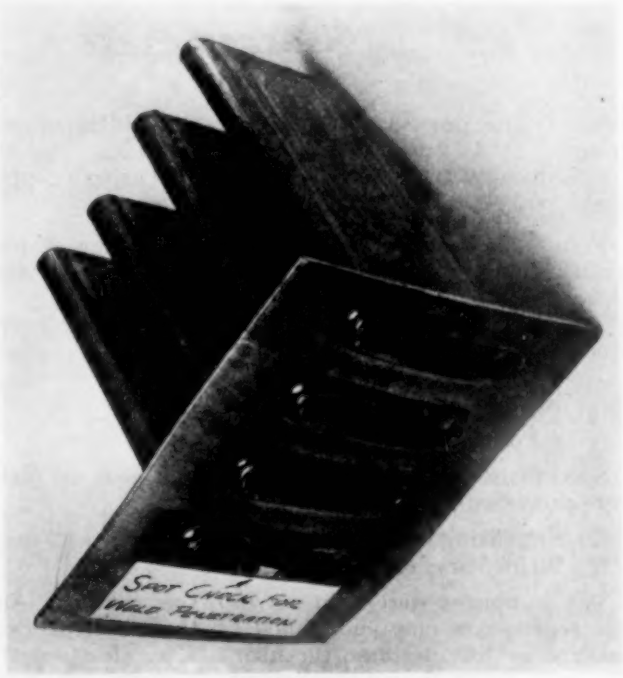


Fig. 1

We will now discuss the laboratory tests which were used to determine the physical and metallurgical results between the oxyacetylene process and the helium-shielded arc-welding process.

A number of specimens were prepared, both in the columbium stabilized (347) and the titanium stabilized (321) stainless steel. The specimens were 4- x 6-in., 0.042-in. sheets with one 6-in. edge of each flanged. These parts were then placed together and tack welded.

One group of these specimens was coated very lightly on the underside of the weld joint with stainless steel flux and welded with the helium-shielded arc process. The

* To be presented at the Twenty-Fifth Annual Meeting, A.W.S., Cleveland, Ohio, Oct. 16 to 19, 1944.

† Assistant Superintendent Manufacturing, Factory A-2, Lockheed Aircraft Corp.

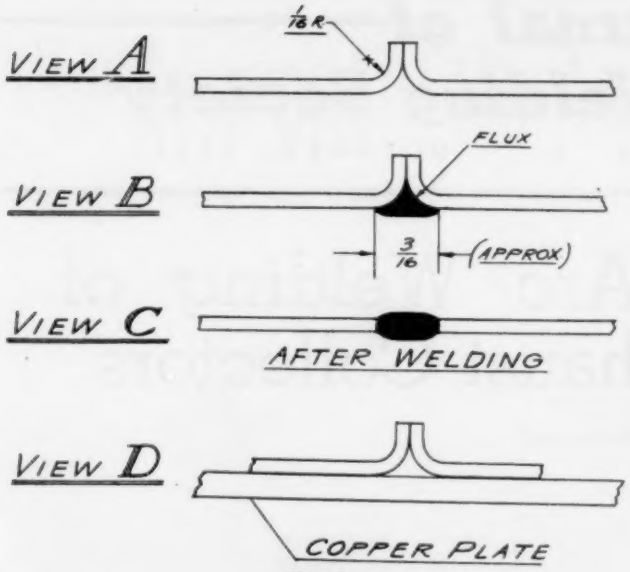


Fig. 2

oxyacetylene process was used in the welding of one group.

Specimens were also selected and welded using a copper back-up plate without the use of flux.

Figure 2 shows view *A*, material flanged; view *B*, material fluxed; view *C*, material after welding; and view *D*, copper back-up plate.

The weld specimens upon which the flux was used were processed as follows:

(*a*) Oakite bath (Oakite Railroad Cleaner).
(*b*) Pickled for 20 min.
(*c*) Sandblast welded area only.

Specimens welded using no flux on the back-up plate were processed as follows:

(*a*) Stabilizing heat treatment at 1800° F. for 15 min.
(*b*) Welded area only sandblasted.

The specimens were then cut into the standard 1-in. side tensile coupons, and pulled by the Physical Test Laboratory to determine the ultimate tensile strength. The variation in the ultimate tensile strength of the coupons from specimens processed by all methods was small enough that no strength advantage could be claimed for one process over the other.

The following table gives a summary of tensile results.

No. of Specimens	Material	Method of Welding	Protection, Underside of Weld	Ultimate Load High	Low	Av.
16	347	Oxyacetylene	Fluxed	3815	3280	3548
16	347	Helium-arc	Fluxed	3970	3170	3720
8	347	Helium-arc	Copper backup	3920	3000	3367
11	321	Helium-arc	Fluxed	3850	3590	3774
4	321	Helium-arc	Copper backup	3900	3635	3759

Sample welds were sent to the Metallurgical Laboratory for weld structure examinations and photographs. All metallurgical specimens were given an embrittlement test as follows:

1. Heat at 1200° F. for 2 hr. to cause precipitation of carbides not stabilized by previous heat treatment.
2. Immersion for 60 hr. in copper sulphate-sulphuric acid solution (Krupp reagent) to cause embrittlement, where intergranular attack is possible due to precipitated carbides.
3. Drop test on steel plate to check for characteristic "ring" of steel not embrittled.
4. Bend test to determine the degree to which steel subject to the above test can be bent without fracture, the said steel should bend 180°.

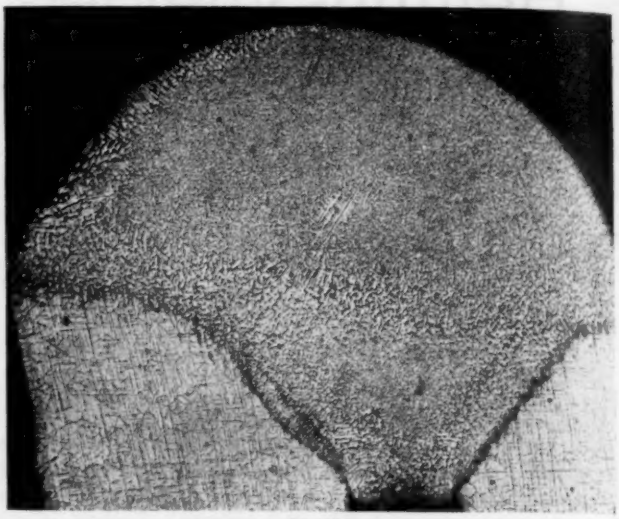


Fig. 3

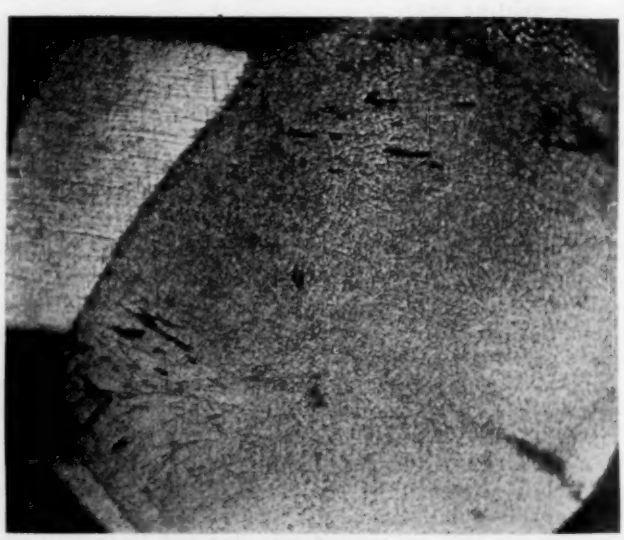


Fig. 4

After processing, metallurgical analysis and photographs, drop and bend tests were made. For comparative results the above was also followed using the oxyacetylene process.

To illustrate the effect of excess amounts of carbon and the presence of oxygen while welding, photomicrographs of a weld made by substituting CO_2 gas for helium are shown in Fig. 3. The carbon burnoff from the electrode was approximately three to four times the rate obtained with helium gas. This weld has good ductility and is considered satisfactory for applications not subjected to heat in service. Poor quality of the weld after being given the embrittlement test is evident as shown in Fig. 4. Also it did not have the characteristic "ring" when dropped on the steel plate. Further, it was not ductile and broke immediately after starting the bend.

The specimen shown in Fig. 5 was welded with a rela-

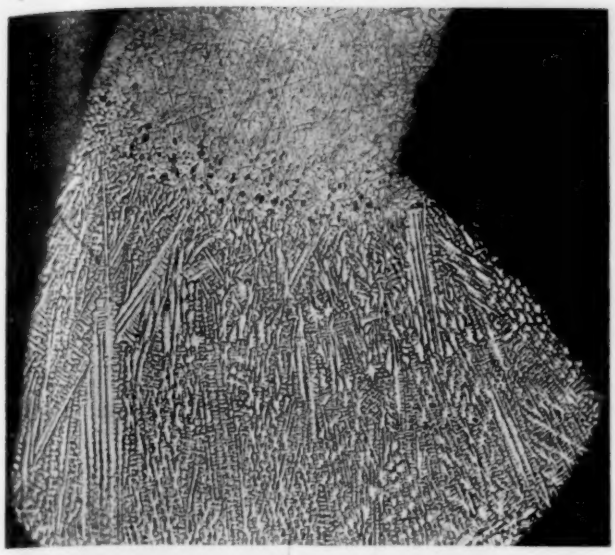


Fig. 5

tively low rate of travel and it will be noted that there is considerable carbide precipitation near the margin between the weld material and the parent metal.

Figure 6 was welded with a high rate of speed and shows considerably less carbide precipitation than Fig. 5, although the welding conditions were the same in both cases with the exception of the rate of travel. This illustrates the desirability of shortening the period of time at which the weld area remains at high temperature.

Therefore, the conclusion may be drawn that the high rate of travel results in less conduction and shortens this time interval.

The following is a short discussion on the welding technique used with this process. As stated previously in the paper, the conventional d.-c. motor-generator arc-weld unit of 150 amp. capacity is used for the weld power supply. The helium-shielded arc torch is fitted with a carbon electrode using straight polarity (electrode negative, work positive).

Figure 7 illustrates the shape of the electrode and shows the torch used. The electrode should be allowed to extend beyond the end of the torch tip approximately $^1/_4$ in. when welding butt or standing-edge seams. A slightly greater extension is required for welding corner fillets. Helium consumption of approximately 5 liters per minute is required.

It is advisable to have a flowmeter attached to the standard regulator, this gives a more constant flow of helium to the torch. Where welding flange-type seams with a copper back-up plate, they should be welded in a flat position. If no back-up plate is used and weld fixtures are not available, tilt the work as shown in Fig. 8. This will help to prevent burning through by encouraging the molten material to flow in the direction of the weld.

When forming exhaust stack parts of similar assemblies made in halves and then fitted together to be welded, it would be preferable to have them formed in steel dies. If all the operations cannot be performed on steel dies at least the finish operation should be so completed. The flange should be formed with a radius of $^1/_{16}$ in. This will be found satisfactory on all gages which normally would be flanged in this manner for welding. The flange height of approximately three times the material thickness is satisfactory and should be uniform along the entire seam. This will permit the welder to make a much more uniform weld and with the addition of very little filler material.

A very light flux is necessary where the flanges are burned down to form a flush weld. Fluxing is not necessary for tacking, standing seam weld, or where a copper back up plate is used. However, in the use of a copper back up plate, it must be clamped tightly to the underside of the joint to exclude the air and serve as a chill.

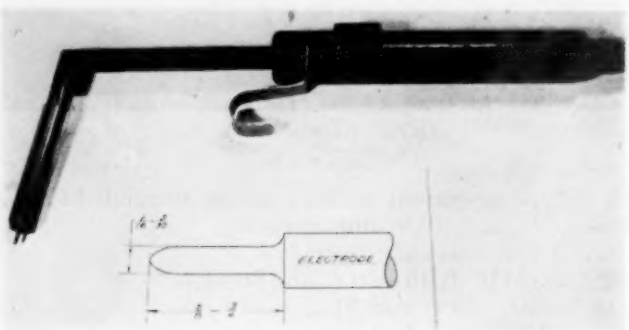


Fig. 7

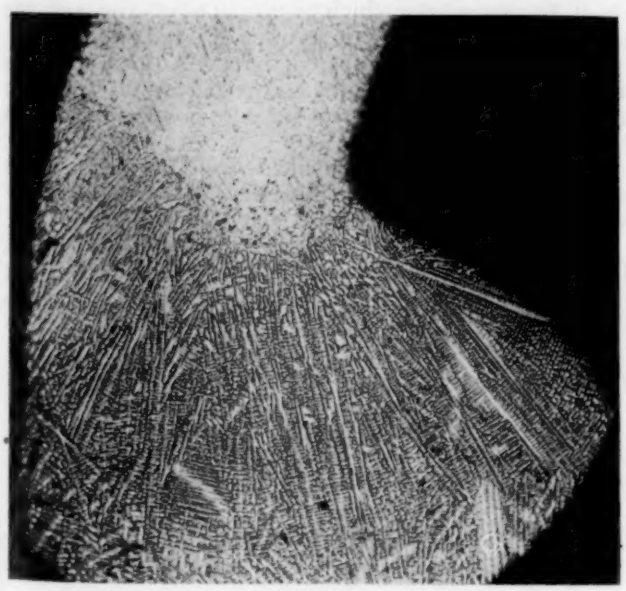


Fig. 6

Fig. 8

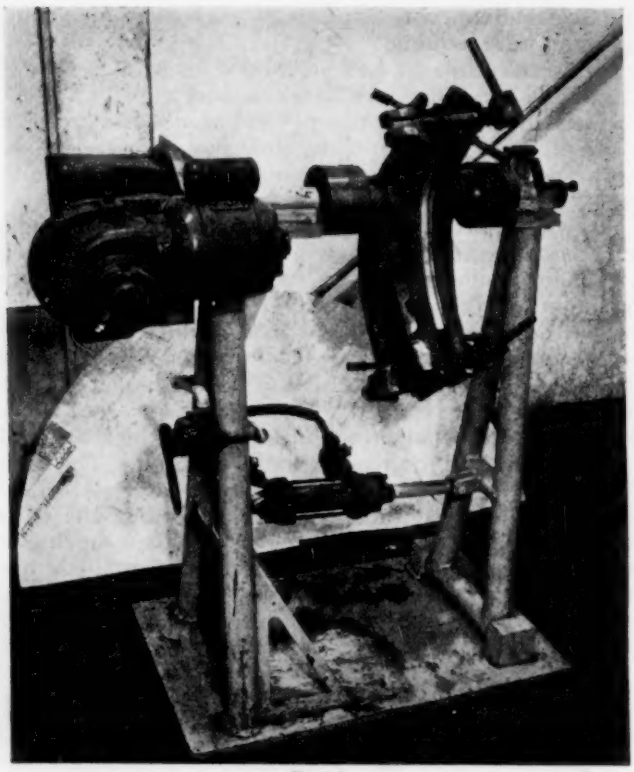


Fig. 9

The following current settings are recommended for use with a machine of 150 amp. capacity.

1. 0.058—60 v. and 75 amp.
2. 0.030 to 0.040—60 v. and 60 amp.
3. 0.011—50 v. and 30 amp.
4. 0.020—60 v. and 48 amp.

On some joints where it is not desirable or possible to use flux or a backup, a small copper tube may be formed to fit the joint and drilled with a series of small holes through which helium could be admitted to blanket the area.

It might be timely at this point to say a little about the weld fixtures. The original drawings for the weld fixtures were obtained from an eastern company. We have improved these as shown in Fig. 9. This fixture is made up of two castings in which each half of a section is clamped. They are then brought together by an air cylinder. Because these castings and the finish die were made using the same basic pattern, the parts will come together without hammering or twisting. When the fixture is closed the welder usually tacks each end of the part and then he may start welding the seams and usually starts the welding from the center and works out. You will notice that this fixture is motorized enabling it to be turned as welding progresses.

The parts are put into the fixture by the metal fitter and taken out when cooled. Because the parts are cooled in the fixture no dinging is required to round out the parts. The ports and other openings are sized on the swage block. These blocks are operated by an air cylinder.

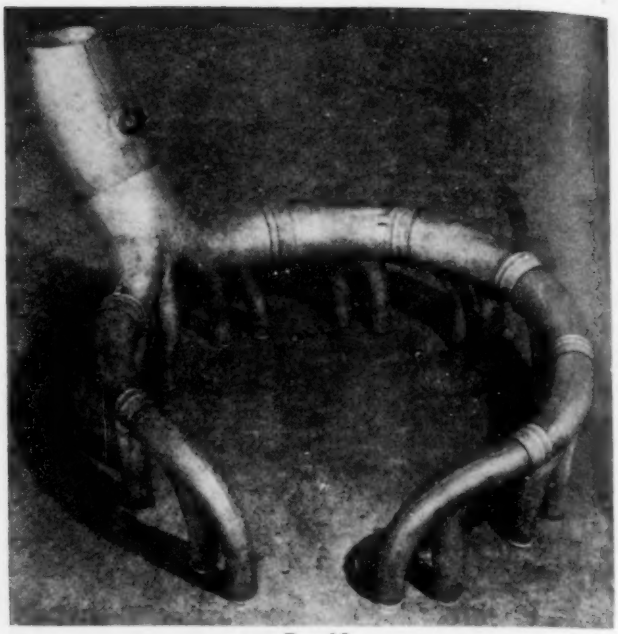


Fig. 10

The parts come to the welding shop from the drop-hammer and hydropress department. Most of the sections were formed in starter dies on the drop hammer. They are finished in a finishing die on the hydropress. Figure 10 shows a completed collector ring welded by the process.

Through the use, and the previously mentioned tests, it has been determined that the helium-shielded arc process is superior to the oxyacetylene process in the welding of exhaust collectors. The area susceptible to carbide precipitation is less, due to the speed and concentration of heat plus the protective helium blanket around the weld and the rate of cooling.

The 347 grade stainless steel stabilized at 1800° F. for 15 min. shows more carbide precipitation in the area adjacent to the weld than the 321 grade but this does not show any deterimental effect on the properties of the weld as shown by the results of the bend tests. The loss in titanium due to welding has not affected the strength of the weld, probably due to a decrease in carbon content in the same area which results in approximately the same titanium-carbon ratio as in unaffected areas.

It must also be remembered that with this process as with any other welding process the parts must come to the weld shop correctly formed. Also good weld fixtures are essential.

By the use of the helium-shielded arc process and the combination of the above points the Lockheed Company was able to save $43,000 in one year.

I wish to acknowledge the help given me by F. C. Pipher in his Engineering Report No. FP-1091, also Jack Porter of Lockheed, Plant A-2, Dept. 17-04.

Arc Welding Practice in the Steel Foundry*

By Frank Kiper and Lawrence Gabes†

IT IS not our intention to imply that our welding practices necessarily are representative of those employed in all steel foundries. We do, however, believe that they are typical, to a large degree, of those found in the more progressive foundries. Ours is a company of five divisions, and in these various divisions we make castings varying in weight from 2 oz. to 50 tons. We have on our books orders from the Army, Navy, oil refineries, rolling mills, railroads, heat-treatment equipment builders, etc. Actually we are what most steel foundries are, although we do not like the name, large jobbing shops; and we have welding problems such as most steel foundries have.

There is a great deal of difference between "knowing how to weld" and "knowing welding." We have a few men in our organization who know welding. These few have set up our practice, taught many other men and women how to weld and are held responsible for the quality of welding performed in the various shops. It is to a large degree through their constant surveillance that we have been successful. We make all the permissible repair welds which our various orders' specifications will allow, and we make quite a few assembly welds as well. Our top management realizing and working on the idea that a job cannot be properly done without good equipments has supplied us with adequate amounts of the best equipment available. As this paper proceeds, and from the accompanying illustrations, this will become apparent as will the fact that our "know welding" men have set up practices which are easy to follow and which fulfill all specification requirements as well as accepted good practice principles.

In four of our five divisions carbon and low-alloy steels are made; while in the fifth, high alloys are made. Of the four, one is an acid open-hearth shop; all the others are acid electric shops. In the carbon and low-alloy steel shops, the allow steels are kept separate from the carbon steels for the purposes of welding and heat treatment. All alloy steel castings and those carbon steel castings having 0.35 carbon or more are preheated to 500° F. and welded before they have cooled to below 300° F. All welding is done on the castings after they have had a preliminary normalize or anneal and before the final heat treatment. If a defect appears after the final heat treatment the casting is again preheated, welded and stress relieved. In the case of a major weld the casting receives a complete reheat treatment. Carbon steel castings are welded either before the normalize or before the draw. This practice assures us of stress-relieved welds in all cases and of heat-treated welds in

* To be presented at the Annual Meeting, A. W. S. Cleveland, Ohio, Oct. 16 to 19, 1944.

† The Ohio Steel Foundry Company.

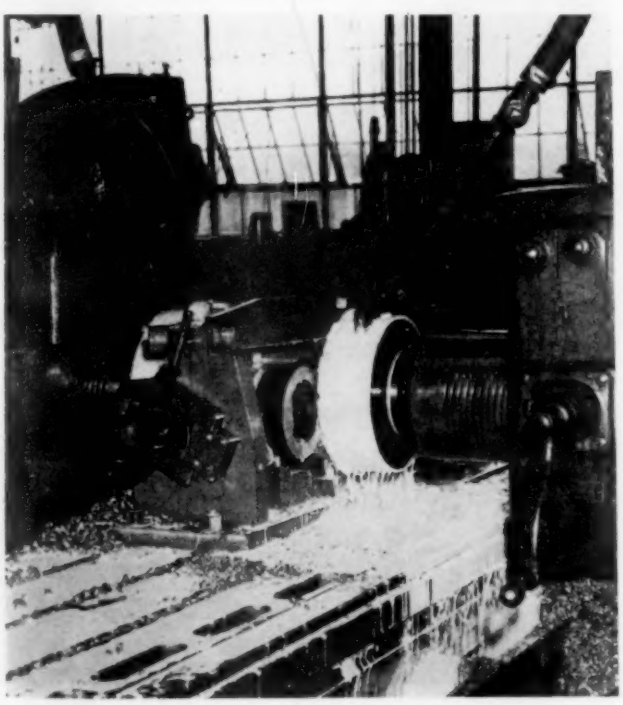


Fig. 1—Rough Machining of Castings

This operation is done after the normalizing treatment and prior to any welding. Many surface imperfections are removed by machining, which eliminates unnecessary welding.

Fig. 2—Air Hammer Chipping of Castings

All imperfections are removed by means of the air hammer. Sometimes an air grinder is resorted to, but rarely on medium and small castings is this necessary.

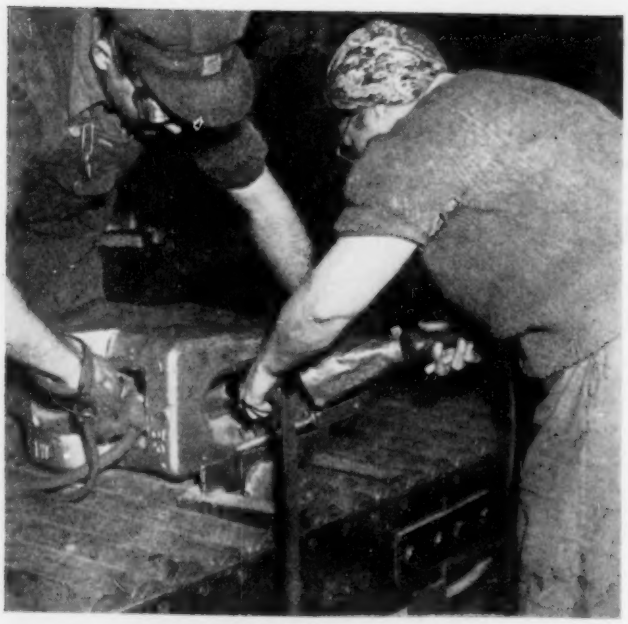


Fig. 3—Magnaflux Inspection

After and during the chipping operation the castings are magnafluxed. This assures the removal of every vestige of the imperfection.

almost all cases. We have found this practice to be well worth while, especially on the higher quality castings, from the standpoint of eliminating hard spots and rendering our casting more machinable.

Another practice which we have established is the rough machining of the castings prior to welding. This removes many surface imperfections and consequently reduces the amount of welding per machined casting. We mention this because we feel that it is worth while, although few foundries have adequate machine tools to do as we do. We sell a large number of semifinished castings, which affords us an opportunity to incorporate this practice.

The North Plant is a specialty shop where many of the breech rings for our Army's guns, up to the 8-in. size, are produced. The steel is produced in a 15-ton acid electric furnace. It is aluminum killed and of a

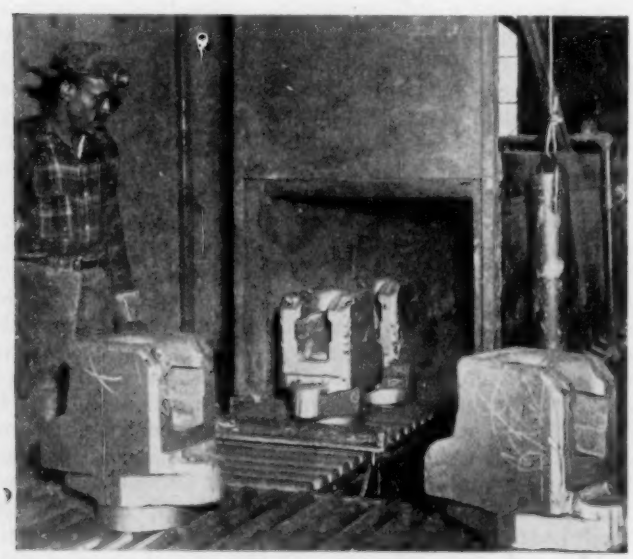


Fig. 4—Preheating for Welding

All alloy steel castings are preheated to 500° F. in such a chamber as this one, and the welding is done on them before they have cooled to below 300°. The preheat reduces the danger of cracking by reducing the thermal shock of weld arc on cold metal.

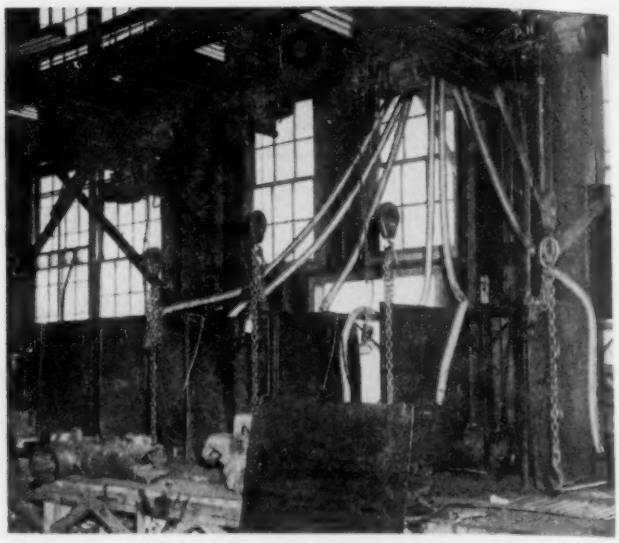


Fig. 5—Welding Booths

At the end of the preheat chambers are welding booths. These, for medium weight castings, are actually stalls; but note the electric hoist and exhaust tube servicing each welder. The welding units sit directly behind the operator in each stall or booth.

medium manganese molybdenum analysis. In addition to the breech ring other high-grade alloy steel castings are produced such as spring seats for tanks, and gun component parts such as yokes. (The welding is done on these castings after the primary heat treatment and the machining operations have been per-

Fig. 6—Welding a 75-Mm. Breech Ring

The casting has been positioned for flat welding. The operator is using a $^{3}/_{16}$-in. coated rod, 150 amp., and reversed polarity. He has at his finger tips a small hammer and a wire brush for cleaning the weld metal slag from each succeeding bead.

Fig. 7—Dressing the Welds

Here the operator is using an air grinder to bring the overlay of the weld to the casting contour. Note that there are no welds on the rough machined surfaces. Rough machining eliminated a great deal of surface welding.

formed.) The defects are removed by chipping and grinding on conveyor lines under inspection. The castings are next magnafluxed with a 600-amp. dry powder magnaflux—surging to 900 amp. After the inspector is satisfied the defects are all removed, the castings are conveyed to a preheat chamber. This chamber is 36 in. x 36 in. x 20 ft. long built on the conveyor line. In this process the castings are brought to 500° F. by soft, natural-gas flames. The doors to the chamber are operated manually and are counterweighted for ease of operation. The castings are pushed through by an air jack. The preheat cycle takes about 40 min.

From the preheat chamber the castings are pushed down a conveyor to the welding booth, which are equipped with 400-amp. motor-generator type welding units of popular make and an exhaust system for the removal of welding fumes; above each booth is located a cross travel, one-ton electric hoist for use by the operator for positioning the castings so that all welding may be done in the flat position. A carbon-moly (50 moly) heavy coated shield arc electrode is used. The standard sizes are $^{3}/_{16}$ and $^{1}/_{4}$ in.; some $^{1}/_{8}$-in. rods are used on thin sections. This particular electrode may be used either on straight or reversed polarity and is used accordingly depending upon the type of weld being made and the operator. Most of the welds are made with reversed polarity. The inspectors have access to the welding booths, and they send back to preheat any casting which has cooled to below 300° F. (as checked by a 300° Tempil Stick) before welding. After the castings are completely welded they are allowed to cool to room temperature in still air. The welds are then dressed by chipping and grinding and sent directly into the heat treatment. After heat treatment the welded areas are again magnafluxed to make sure no breech ring or other high-quality casting gets to our final line with a defective weld in it. This particular weld line employs 12 welders.

Fig. 9—Final Inspection

In the case of Breech Rings the castings are magnafluxed again after welding. In all cases the final inspection is in the customer's representative's presence. A large percentage of our work is for the Ordnance Department and so must undergo ordnance inspection.

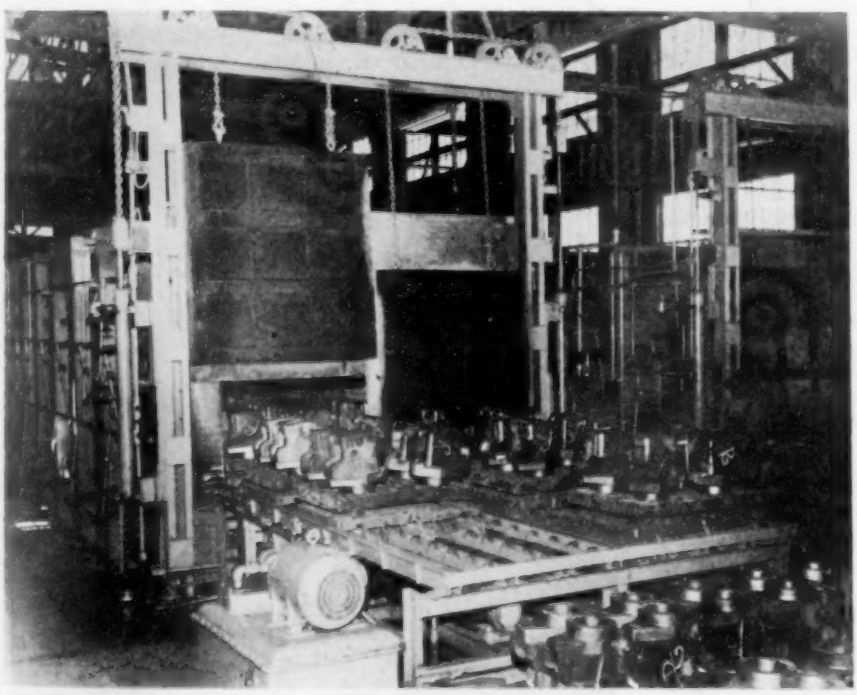


Fig. 8—Stress-Relieving Treatment

Those castings which need some minor repair after the final heat treatment are stress relieved at a temperature 50° lower than the draw treatment temperature. Here are shown such castings emerging from a continuous heat-treating furnace.

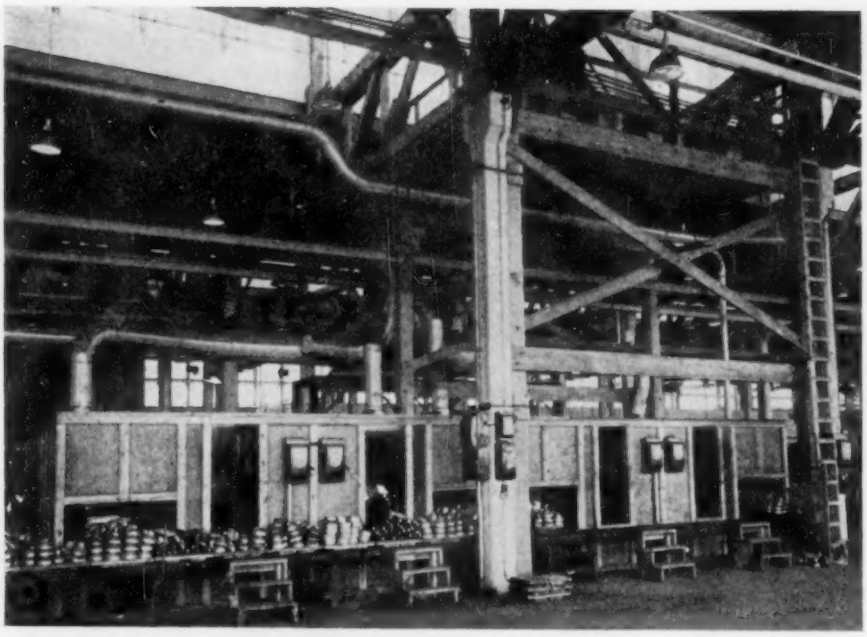


Fig. 10—General View of Welding Booths for Small Castings

This is the type booths supplied for small castings. Every booth is serviced by conveyors and has an exhaust system in it.

In addition to the "breech ring" welding described above a slightly different setup is used for another type of casting produced in the North Plant. A large number of valve bodies and like castings are produced. The bodies range in size from 8 to 24 in. and from 150 to 1500 lb. The high-pressure valve bodies are, of course, made in low-alloy steel and are preheated to 500° F. before welding with a carbon-moly electrode. The low-pressure (300 lb. and under) valve bodies are welded with a low-carbon steel, shielded-arc electrode of the straight polarity variety. The defects on this type of castings are prepared for welding by either the chipping hammer or the oxyacetylene gouging torch. Of course, when the gouge is used the slag resulting is removed by the shipping hammer. The welding is done by six welding operators, and 300- and 400- amp. motor-generator units are used.

The South Plant is a small castings plant. It produces large numbers from a few patterns—all of only a few pounds weight. For this reason they are easily handled, and most of the welding is done by women. The steel is produced in 5-ton acid electric furnaces, and in addition to carbon steel, a modified NE 9430 steel (nickel-chrome moly) is produced. The alloy and carbon castings are kept separate for welding and heat-treating purposes. All carbon steel castings are prepared for welding by chipping on wooden benches, inspected and loaded on skids for conveying to the welding booths.

The welding booths are constructed on plywood and are approximately 9 x 10 ft. and 8 ft. high. Each booth is equipped with an exhaust system. A roller conveyor runs along each side of these booths and a cross-over section runs through each booth. Each operator has a 400-amp. motor-generator welding unit at his disposal. The castings arrive in the booth from one side, on skids. They are usually removed one at a time, welded in a jig and placed on another skid. When the skid is filled it is pushed outside the booth to the chippers and weld dressers where the castings are finished and inspected before being sent to heat treatment. This welding is done with $^{5}/_{32}$- x 14-in. electrodes of the carbon steel, heavy shielded, straight polarity type. Each operator welds between 700 and 1000 castings per 8-hr. day and uses an average of 150 electrodes. The alloy castings follow the above procedure except that they are preheated to approximately 500° F. and are welded with $^{3}/_{16}$-in. reverse polarity carbon-moly electrodes. After welds are cool they are dressed and inspected and sent on to heat treatment.

What has been said of the South Plant might be said for the Springfield Plant also, with a few exceptions. The Springfield Plant is an acid electric plant producing aluminum-killed carbon and alloy steel castings. There is a large number of patterns being run at all times as well as a greater variety of alloys than in the South Plant. The welding technique, however, is the same—conveyor line production, preheat chambers and continuous heat-treating furnaces. Motor-generator welding units are used and the shield arc electrodes used are the same as used at the South Plant.

The Central Plant is the acid open-hearth shop, producing miscellaneous castings such as power shovel and locomotive parts as well as rolling mill rolls and large refinery pipes. The castings vary in weight from 55 lb. to 50 tons and are of such varied sizes and shapes as to render them unsuitable for the production line system of working them. The smaller ones, however, are worked on rail skids on benches. One inspector and one welder are stationed at each group of six chippers. This enables the inspector to pick out the alloy castings for preheating as well as inspect both before and after welding.

The larger castings are worked on the floor under the eyes of an inspector. Where possible the defects are removed by air hammer chipping, but when necessary the flame gouge is employed. Flame gouging is always fol-

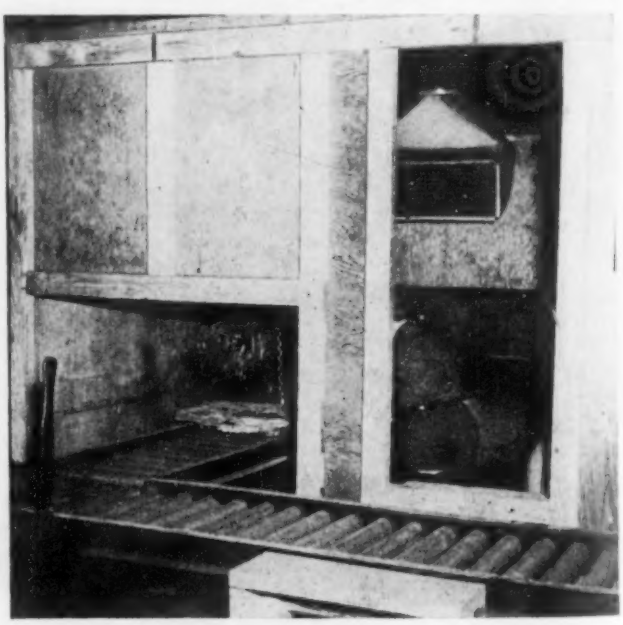


Fig. 11—Welding Booths for Small Castings

Note crossover conveyors, exhaust hood, steps, welding units and woman welder.

lowed by chipping in order to be sure the defect and slag from gouging are removed. A conscientious effort is made to do as much welding as possible in the flat position. Jib cranes and bridge cranes are used for positioning due to the design of some of the castings, however, some vertical welding is necessary. This welding is done by the weave technique. The electrodes used are the heavy shield arc type of $^1/_8$- to $^1/_4$-in. sizes, and the analysis is chosen to watch the subject casting as nearly as possible.

The large, high-pressure, alloy steel refinery fittings and pipes are repaired by the same procedure as is used on breech rings: the defects are removed under magnaflux inspection. The castings are preheated to 500° F. and welded before they have cooled to below 300° F. (In the case of large castings where there is danger that they might cool to below 300° F. the temperature is maintained by means of natural gas flames and asbestos coverings.) After welding, which is done by stringer or weave technique dependent upon size and position of the defect, is complete, the casting is given its final heat treatments. The welds are dressed by chipping and grinding, and the castings are again subjected to the magnaflux test. These castings generally undergo a hydrostatic test of 1000 lb. for 24 hr. also.

The welding machines used in this plant are the 400- and 600-amp. motor-generator units. There are 36 welders employed. Two carbon steel electrodes, one straight and one reversed polarity, and four alloy electrodes are used with regularity. The average monthly consumption is 13,000 lb. of electrodes.

The high alloys are produced in two acid-lined electric furnaces, one of 1000 lb. capacity and one of 500 lb. capacity. Most of the work is the heat and corrosion type. However, many analyses are made, the most popular of which are 18–8, 25–12 and 25–20. A great deal of care has to be exercised in selecting rods for welding these materials, but there are many on the market today which do a satisfactory job. An understanding of the material being welded is equally important and recently this understanding has been popularized.

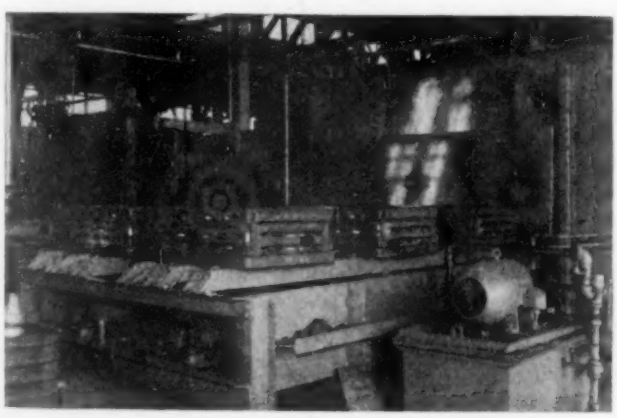


Fig. 12—General View of Heat-Treating Furnaces

The continuous-type heat-treating furnace has become very popular at the Ohio Steel Foundry Co. Above are pictured the loading ends of two such furnaces for small castings. We have recirculating type continuous furnaces for the low temperature, up to 1300°, treatments.

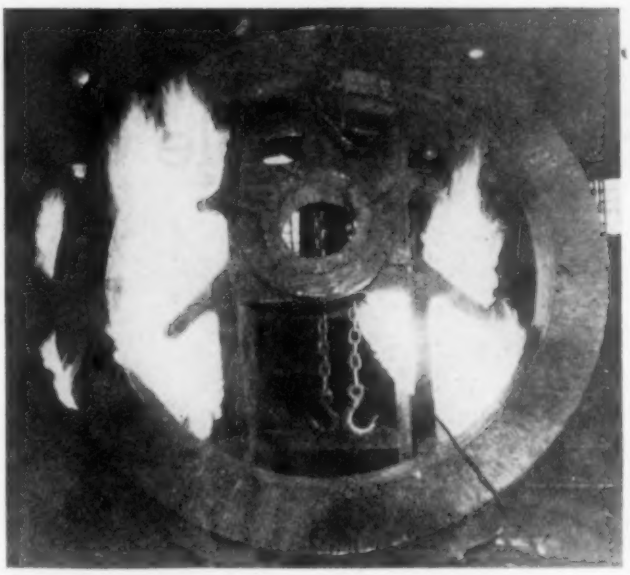


Fig. 13—Preheating Large Castings

This photo depicts a method employed to maintain the preheat temperature on large castings. When the temperature falls to near 300° large natural gas flames are allowed to play on the casting. It has been found that the heat input by this method is very gradual. Many very large castings have been treated thusly. The initial preheating for this casting was, of course, done on a large cartype furnace. The gas flames serve mainly to maintain the temperature of the already preheated casting.

Our general practice is as follows: Select a rod which will produce a weld to match the parent casting. (We use flux-coated rods so as to avoid oxidation losses during welding.) Reversed polarity is employed in all cases and the current setting is as low as is consistent with good penetration.

We have to bear in mind that carbide precipitation is injurious to the casting and is to be avoided. This may be done by avoiding too long a time at temperatures within the carbide precipitation range and by keeping the carbon content of the alloy low. We also bear in mind that the alloys melt at lower temperature than do steels, have greater coefficient of expansion (chromium steels excepted), conduct heat more slowly and resist electric currents much more strongly than do steels.

Our welding personnel's experiences range from beginners to 30 yr. experience. A training school is conducted under the State Vocational Education Program. The beginners are taught the fundamentals on steel castings that we have scrapped. After they have mastered the fundamentals they are put on the floor under competent welding foremen to do relatively unimportant welding until they get the feel of working in the shop. From this point the operators progress at their own rate. Every operator of 6 mo. experience or more is given a test every 6 mo.

The following slides depict the principles which we have stressed in our practice:

1. Rough machining.
2. Magnafluxing.
3. Preheating.
4 Stress relieving.

Small Portable Condenser Welding Set*

By E. M. Callender†

Introduction

A NEW application for the condenser discharge welder relating particularly to welding stainless steel is described in this paper. The portable discharge welder is one of four units comprising a complete field repair outfit. This welder is light, mobile, and employs an unusually small welding transformer. It is designed to operate in conjunction with a portable hand air gun, and with long secondary welding cables that produce a much higher impedance secondary circuit than is normally permissible in most discharge welding machines.

In contrast to the heavy appearing discharge welders we ordinarily think of, are many types of small bench discharge welders that are used for light work. However, none of these machines is of the portable type in the sense that it can cover the welding on a large spot-welded assembly.

Engineers concerned with the project of an all-stainless-steel cargo plane realized that for emergency repair in remote localities a lightweight repair welder of low power demand would be essential. The power plant for a comparable a.-c. resistance welding machine must provide at least 50-kva. output whereas the discharge welder described is used with a 5-kva. power plant.

It will be desirable to review briefly some discharge welder fundamentals, and then to explain those departures from conventional practice which made possible the considerable reduction in weight. The major departure is in the unusually short welding time. These principles were first described in the initial Adams Lecture by Dr. C. A. Adams.

The short-time weld is a sturdy weld made with much less energy than a conventional a.-c. spot weld. There is some tendency toward surface spitting, particularly on the heavier gage of 0.040 in. and with very short times. This can be largely reduced by high electrode pressure and is not an important factor for emergency repair. The appearance of the weld in 0.010- or 0.020-in. stainless is excellent, there being little marking.

Portable Repair Welding Equipment

The units comprising the complete equipment consist of:

1. Portable Power Plant (Fig. 3).
2. Portable Discharge Welder (Figs. 1, 2, 3, 4).
3. Portable Arc Welder (Fig. 3, background).
4. Portable Work Bench that contains all tools and materials (Fig. 2, background).

The portable welding equipment chosen for the job followed a survey of various methods and combinations of equipment that might yield the required result of lightness and portability. Consideration, for example, was given to:

(*a*) A special 400-cycle frequency 3-phase power plant and rectifier.
(*b*) Storage batteries floating on a small generator.
(*c*) Special a.-c. resistance welders.
(*d*) Stored energy form of welder.

The condenser discharge welder proved to be the best from a weight standpoint, and probably best in accuracy of welding performance utility. At the same time the other related equipment proved lighter and more satisfactory.

The repair equipment centers around a condenser storage discharge welder of 360 microfarads and 3000 v. peak charge. It could operate effectively on 400-cycle frequency and use a 3-phase source of supply, but it was ultimately designed to operate on 115-, 230-, 460-v. single-phase, 50 to 75 cycles source. As an illustration of the low power demand, the welder can be made to operate from a standard 115-v. a.-c. receptacle. It will weld two thicknesses of 0.040-in. stainless steel, three pieces of 0.035 in. stainless, and pile-ups of lighter gages such as eight pieces of 0.020 in., with weld shear strengths comparable to a.-c. resistance welds.

The portable welder is shown in Fig. 1 ready for transporting. A supporting structure for the welding transformer and cable can be assembled from the handles as shown in Fig. 2. The welding transformer suspended from the support weighs only 80 lb. complete and may also be carried in or about the plane structure.

One feature of the discharge welder is elimination of water cooling that is required with a.-c. welders. This brings about considerable weight reduction and is obtained by reason of a higher welding efficiency. In fact, the welder complete with cables and transformer weighs but 775 lb.

Construction of the cabinet includes welded, carbon steel form break section frames that are rugged, although light. The combination of wheel and skid mounting support can be seen in Fig. 1, the simplicity of braking restraint being supplied by use of skids.

The other equipment operating with the discharge welder will be discussed briefly.

The power plant is a gasoline-driven unit with a self-excited generator which will supply over 5 kva. at 115

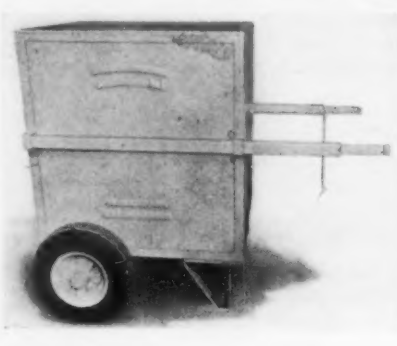


Fig. 1—Discharge Welder Ready for Transportation

* To be presented at the Twenty-Fifth Annual Meeting, A.W.S., Cleveland, Ohio, Oct. 16 to 19, 1944.
† Edward G. Budd Manufacturing Co., Philadelphia, Pa.

v. a.-c. single-phase 60-cycle current. A fast acting automatic speed governor is essential on the engine, particularly for the arc weld load. A constant voltage regulating transformer is also included to regulate the voltage on the load control circuits. An air compressor, electrically driven, has been built into the power plant to furnish air to welding guns or air tools. All together the power plant as shown in Fig. 3 (inset) weighs about 950 lb. and is of the same general construction as the discharge welder.

The d.-c. arc welder (background Fig. 3) operating from the above source is utilized for emergency repair of any gages above 0.040-in. stainless steel. Its characteristic is such as to maintain stable arc currents from 20 to 100 amp. The highest current is useful for cutting out structural sections that must be replaced. A further interesting application of the arc welder is found in charging plane batteries. The arc welder weighs 350 lb.

The tool bench (Fig. 2) contains a large group of tools. One reason for this is the need for a large variety of welding guns and their extending arms from air cylinder

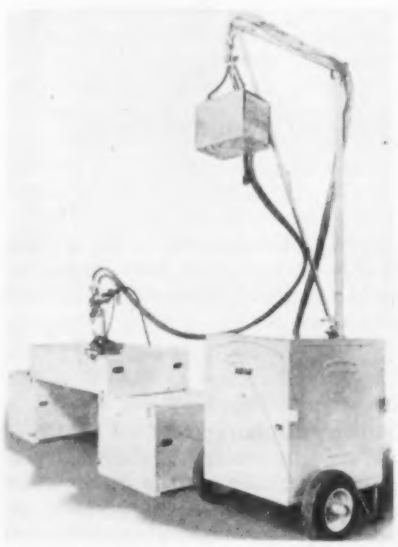


Fig. 2—Handles Formed Into Overhanging Support for Discharge Welder Transformer; Workbench in Background

to welding tips. These "yokes" can be formed from copper bar, which has been included for the special cases. Several tools are required for this forming work. Most of the tools are used for repair work, however. The total weight will run about 800 lb., so that three sections make up the bench for separate handling during transportation.

Operation of Discharge Welder

The portable welder is controlled from the welding gun by a combined air valve and electric trigger switch. Controls on the main panel govern voltage settings (Fig. 4). Operation is obtained from a circuit having a minimum of apparatus and electronic control, and 20 welds a minute may be made continuously.

The welding transformer may be located a distance of 75 ft. from the welder with an additional 15 ft. of secondary cable to the welding gun. However, the welding transformer ratio and required energy may dictate the secondary cable length, and on some heavy work the preference of a higher transformer ratio necessitates a reduction in cable length to perhaps 6 ft. length.

The rear of the discharge welder (Fig. 3) contains the connection panels. Individual twist type plugs provide good high voltage connections. The primary cable

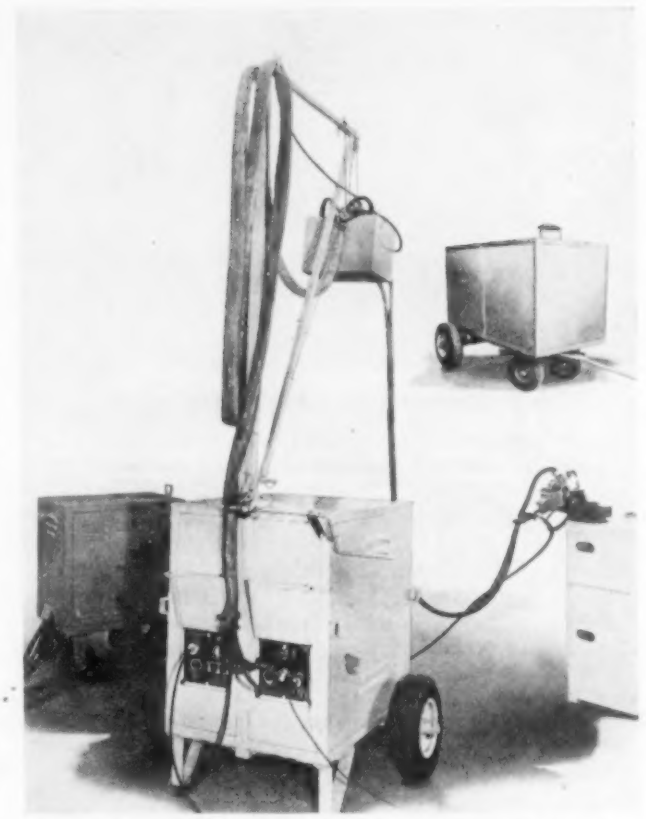


Fig. 3—Rear View of Discharge Welder; Arc Welder in Background. Inset: View of Power Plant Cabinet

bundle (seen enclosed in fire hose protective casing) further includes air hose, electrical operating cord, and a safety ground wire. A winding reel for the transformer support makes it convenient to raise the weld transformer into place.

Other features include interlocks on all panels to discharge the condensers and further prevent operation should anyone open the unit. The welding secondary is grounded, so that in the event of transformer breakdown the operator is completely protected. The primary cables plug right into the welding transformer case. Each unit is built for assembly in the discharge welder cabinet with the object of easy removal and replacement in case of maintenance or failure.

Principle of Operation of the Discharge Welder

A brief analysis of the operating principle of the discharge welder is now made, with particular emphasis on the function of the welding transformer.

First, the circuit is taken in elementary arrangement,

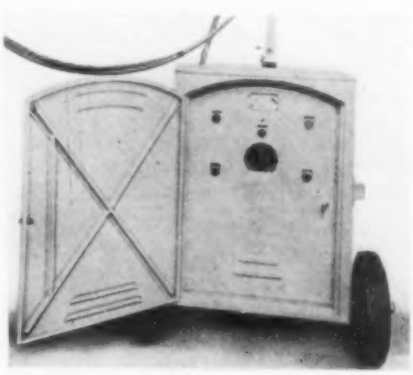


Fig. 4—Discharge Welder Front Panel

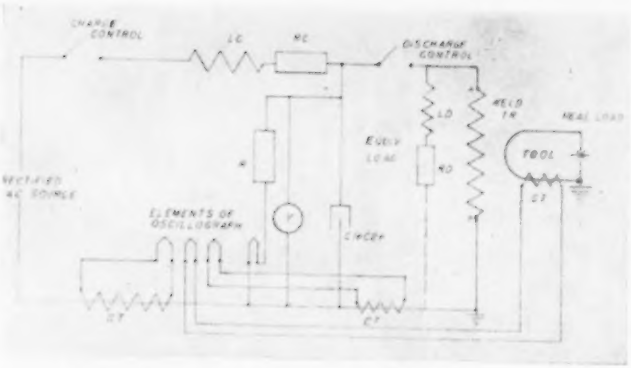
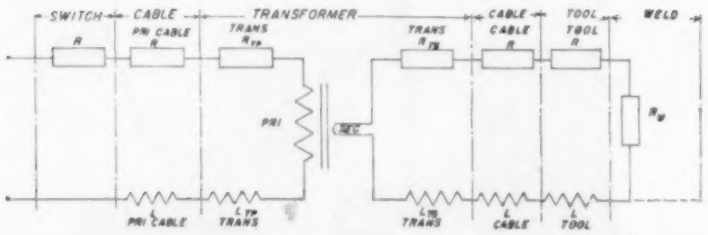


Fig. 5—Elementary Discharge Welder Circuit

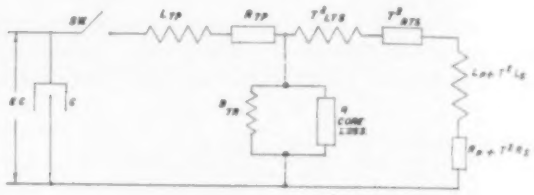
$$Q = it = \int_{t^1}^{t^2} idt \qquad (2)$$

Equation 2 immediately establishes the fact that by changing the current and time, the rate of charging or discharging a given quantity of electricity can be varied over wide limits. This is a valuable feature for obtaining the low power demand required of a portable unit such as this. The current is limited partly by reactance built into the charging transformer, and partly by series resistance. In the portable welder 100 cycles charge time is not considered excessive.

The energy is stored in the capacitors by rectified a.-c. However, to simplify this discussion considerably, a constant voltage E may be impressed on the capacitors



(a) Summation of Lumped Resistance and Inductance Around the Circuit



(b) Equivalent Transformer Circuit

Fig. 6

as in Fig. 5. A dielectric potential stress will be imparted to the condenser during a passage of current through the circuit.

$$E = \frac{1}{C}\int_{t^1}^{t^2} idt \qquad (1)$$

Total flow is known as a charge Q and represents quantity of electricity that passed by some point in the circuit over a given interval of time.

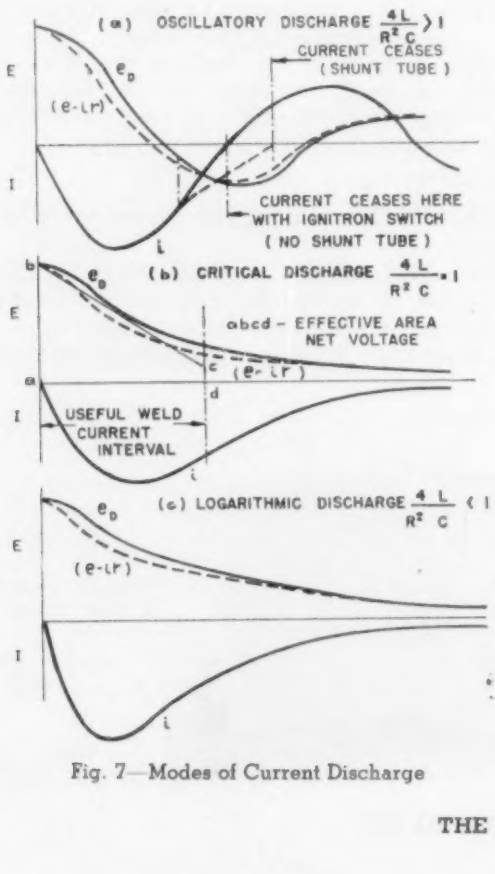

(a) OSCILLATORY DISCHARGE $\frac{4L}{R^2C} > 1$
CURRENT CEASES (SHUNT TUBE)
CURRENT CEASES HERE WITH IGNITRON SWITCH (NO SHUNT TUBE)
(b) CRITICAL DISCHARGE $\frac{4L}{R^2C} = 1$
abcd - EFFECTIVE AREA NET VOLTAGE
USEFUL WELD CURRENT INTERVAL
(c) LOGARITHMIC DISCHARGE $\frac{4L}{R^2C} < 1$

Fig. 7—Modes of Current Discharge

to produce a final charge Q. Energy expended is QE or $E \cdot i_{av} \cdot t$. At least half this energy goes into circuit resistance losses and with a perfect capacitor the stored energy resulting is well known as:

$$J \text{ stored energy} = QE/2 \text{ or } {}^1/_2CE^2 \qquad (3)$$

joules in the practical system.

The stored energy will be discharged into a load as in Fig. 5. An illustrative welding circuit is shown in Fig. 6 (a), and since the weld resistance (in the order of 100 microhms) is but a small part of the total equivalent circuit resistance, it is apparent that only a small portion of the stored energy will go into the weld itself. However, the short-time weld uses very little energy. Then, too, this energy is put into the weld at a high power rate, which is favorable for welding. You will recall the other extreme in which, with an insufficient power rate of weld current flow, no amount of energy will produce a weld.

In the stored-energy capacitor welder three modes of discharge are possible (see Fig. 7). The type mode of current discharge may be discerned by the ratio $4L/R^2C$ (Appendix 1). In practice it is most usual to find the oscillatory type discharge, and in the portable repair welder this is likewise true, despite fairly large cable re-

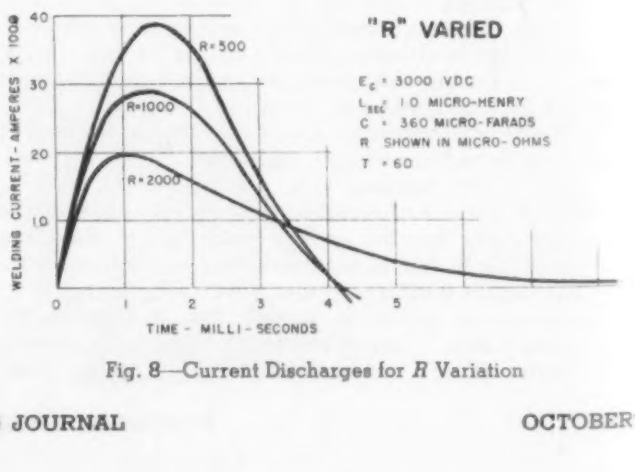


Fig. 8—Current Discharges for R Variation

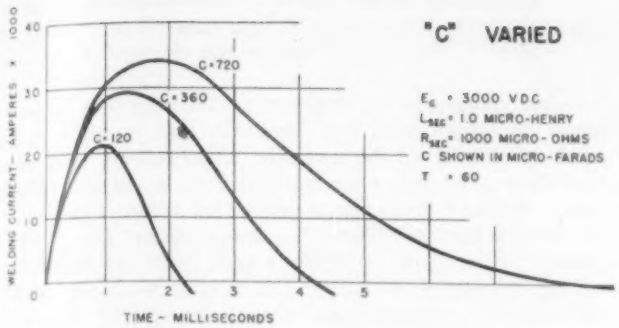


Fig. 9—Current Discharges for C Variation

sistances. The critical case ($(4L/R^2C) = 1$) is quite instructive, however. It is a borderline case between oscillatory and logarithmic discharge, and its envelope develops rapidly in a direct manner. Since its envelope contains more high rms. value current around its peak value, it is an effective wave form and is useful from a comparison standpoint at least. In the portable discharge welder every effort is made to keep the oscillatory discharge near the critical case so as to utilize more energy in the first current loop and to lower detrimental reverse voltage on the capacitors. It is done by choosing the transformer turn ratio to match the welding secondary cables used. This now brings us to the welding transformer, which is the coordinator of all discharge welders (also refer to Appendix 2).

The welding transformer is a current step-up device that exerts considerable control over the welding current wave form and, incidentally, its magnitude. Changing the ratio of windings allows a lengthening of time of current flow at a sacrifice of current magnitude or the converse (see Fig. 10). One other important feature should be credited to the transformer. It reduces the voltage in the welding circuit to safe values. The transformer is thus vital, for though the time of flow might conceivably be lengthened without it by using inductance, there would still be the disadvantage of high oscillatory discharge and full capacitor voltage on the circuit.

In descriptive analogy the transformer makes the primary circuit "see" a high impedance with consequent low current flow and causes the secondary circuit to "see" low impedance, transferring energy to the latter to produce high current flow. This, of course, is well known, but a review of fundamentals is always helpful. The transformer equation is:

$$\frac{N_p^2}{N_s^2} = \frac{R_p}{R_s} = \frac{L_p}{L_s} \tag{4}$$

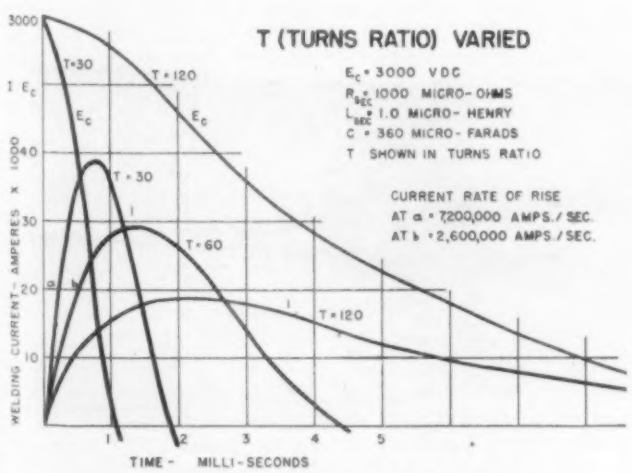


Fig. 10—Current Discharges for T Variation

or

$$R_p = R_s T^2 \tag{5}$$

and

$$L_p = L_s T^2 \tag{6}$$

where

$$T = \frac{N_p}{N_s} \tag{7}$$

Remembering the mode criterion $4L/R^2C$, it is seen that high transformer ratios reflect more secondary resistance than inductance into the equivalent primary term tending to make $4L/R^2C$ approach 1, which changes the oscillatory discharge toward a logarithmic type discharge (Figs. 6 (*b*) and 10).

The effect of varying any parameter C, L, R or T are set forth in curves (Figs. 8 to 11) for conditions that approach the constants used in the portable set. An interesting analogy is drawn between Figs. 10 and 11. In-

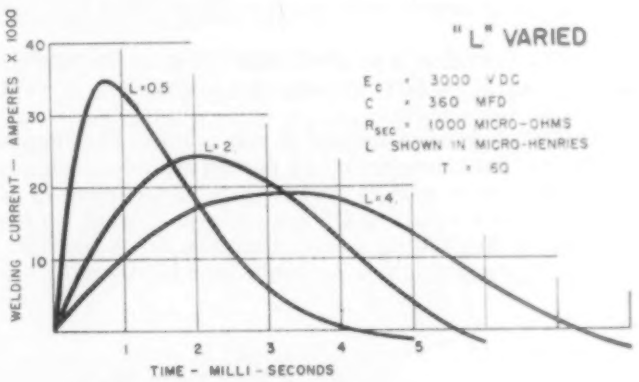


Fig. 11—Current Discharges for L Variation

creased time is obtained by increased inductance (Fig. 11) and by turns ratio (Fig. 10). More oscillatory discharge then occurs for Fig. 11 (inductance increasing) and less oscillatory discharge for Fig. 10 (turns ratio increasing). In fact, for $T = 120$ the discharge is logarithmic. The discharge condenser voltage is also plotted for two cases in Fig. 10.

An endless array of discharges may be chosen by controlling the combined relationship of charge voltage, transformer ratio, capacitance, inductance and resistance.

The exact discharge form will have considerable bearing on the kind of weld obtained and on the annealing, forging or any other effect desired. Of importance are:

(*a*) Rate of rise of current.
(*b*) Rate at which energy is being put into weld at its inception.
(*c*) Time duration of sufficient energy to continue fusion as well as the succeeding rate of energy flow after weld inception.
(*d*) Energy duration at the tail for annealing in some cases.

In practice a contactor or an ignitron which was used in the welder shown, may be used to close the discharge circuit. A second ignitron shunted across the transformer primary will prevent undesirable reverse voltage on the condensers, and will produce a logarithmic decay shown in Fig. 7 (*a*).

The Short-Time Weld

The short-time weld might be defined as that weld produced during the flow of half-cycle current whose time to peak is less than the time to peak of a 60-cycle sine wave. In this portable welder the time to peak is from 1 to 3 milliseconds.

A typical pattern of the etched section of a short-time weld is seen in Fig. 12 (*a*) and (*b*). Both welds were made in 0.020-in. half hard stainless steel with a peak current time less than 1 millisecond, and 19,000 amp. The etch Fig. 12 (*a*) differs from 12 (*b*) in that the latter had emory polished contact surfaces. Hence, less energy was received in the weld (Fig. 12 (*b*)) because of lower contact resistance. The latter etch is a good sample of the short-time weld. Intergranular fusion (not to be taken as part of the weld nugget) is seen extending around the weld in Fig. 12 (*a*). An additional point of weld formed initially is visible on the left-hand side.

A short-time weld differs in configuration from the a.-c. resistance weld for several reasons.

1. The rate of power input for a short period is relatively much higher.
2. Higher equivalent frequency or rate of rise of current (producing greater skin effect) can cause the weld to commence as an annular ring instead of as a point from an axial center (note points *a* and *b*, Fig. 10, also Fig. 12 (*a*)).
3. The duration is so short that the heat flow cannot finish its job of pattern forming that it does in a.-c. welding.
4. The short-time nugget is just a wafer-like nugget bond sometimes surrounded by partial granular fusion of little significance, except that it may be deceiving in an etch inspection as in Fig. 12 (*a*). The a.-c. weld, on the other hand, has a weld nugget that has grown considerably more along the axis perpendicular to the weld surface.
5. Additional small fused areas occur in some instances in certain portions of high current paths. These are notably in the corners under the electrodes (see Fig. 12 (*b*)).

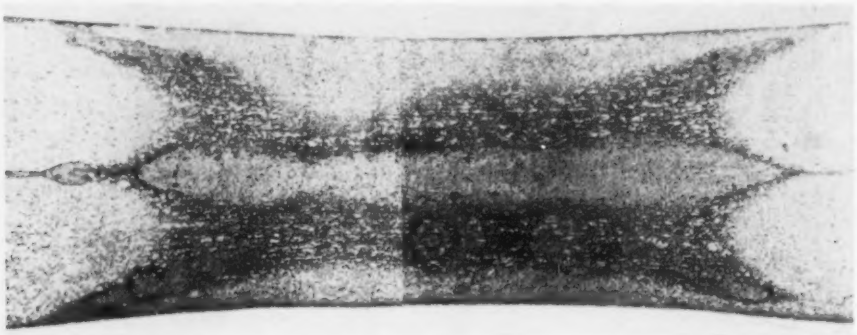
A thin nugget is formed with relatively few joules of energy in these short-time welds. The bond of fusion has been found to be entirely satisfactory, and tests show that good shear strength and resistance to fatigue result. Table 1 gives shear values for various gages.

It is essential to discuss to some extent the possible application of this portable repair unit to aluminum welding. Results to date indicate that with the Alclad such as 24 ST a longer time to peak is required than with stainless steel. Experiment has indicated that 4 milliseconds would be sufficient. Therefore, with larger ratio transformers, such as 100, 200 or 300/1, there is no reason why aluminum cannot be welded. In fact, it is being done with an equivalent amount of storage. The portable work tool cannot be maneuvered as well, however, since with these higher ratios the welding secondary cables must either be greatly shortened or become rather cumbersome.

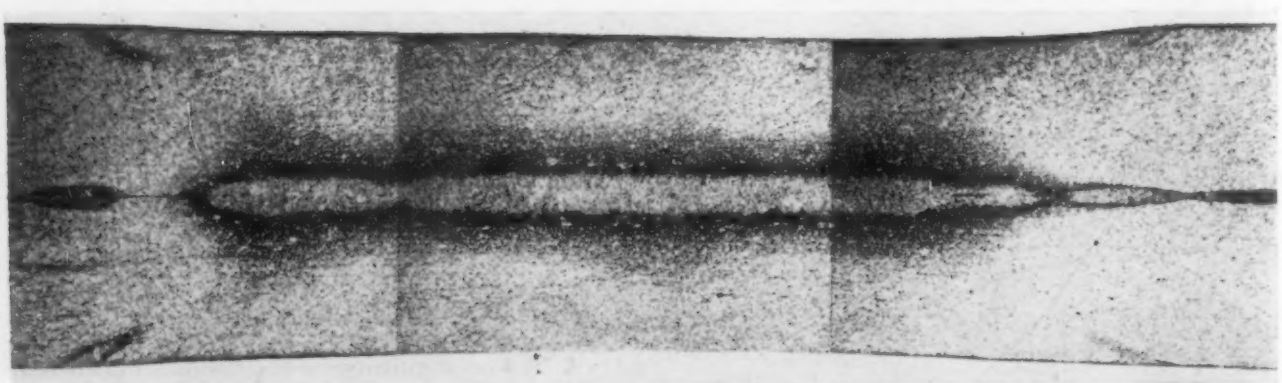
There are doubtless other metals that can be successfully welded with the short-time weld. Carbon steel has been welded in 0.030 in. gage. Others, such as brass, have not been tried as yet. The tool tip force used in every case is found to be comparable to that used with straight a.-c. resistance welding. There is some advantage to higher tip force than is normally employed, both from strength standpoint and from appearance on the outside of the weld.

Principles Used in Portable Welder Design

Certain principles were involved in producing welds in stainless steel with a limited capacitor bank and with further weight limitation imposed on equipment.



(*a*)



(*b*)

Fig. 12—(*a*) and (*b*) Micrographs of Typical Welds

Table 1—Typical Shear Strength, Portable Discharge Welder

Material: stainless steel, half hard
Capacity: 360 microfarads
Electrodes: Mallory, 2½ radius
Cable Length: for 30/1 ratio: 2–10-ft. 4/0 cables
for 57/1 ratio: 2– 4-ft. 4/0 cables

Identity	Pile-up and Gage	Volts (Av. Setting)	Weld Transformer Ratio	Tip Force (Av.)	Shear Pull Strength High	Low	Av. (for 10)	A.-C. Weld Min. Chart Strength A.W.S.
1	2-010	1400	30/1	450	350	300	310	275
2	2-020	2200	30/1	500	900	660	750	650
3	2-030	2500	30/1	575	1330	1080	1200	1180
4	2-030	2500	57/1	575	1400	1200	1250	1180
5	2-040	2750	57/1	600	1800	1450	1650	1850
6	4-020	2300	30/1	450	900	870 (Middle)	..	650

1. The short-time stainless steel weld is metallurgically sound, possesses excellent properties of shear and fatigue strength; and although the fusion nugget is thin, being known as a wafer, this is not necessarily detrimental.
2. The size of welding transformer (aside from its resistance) depends on length of weld time (see appendix 2) and hence can be made light in weight only for a "short-time" weld.
3. A short-time weld can best be accomplished by using a lower transformer ratio than is employed in conventional discharge welders. This also has the further advantage of facilitating higher welding currents. Studying Equations 32, 34 and 36, it becomes apparent that as the ratio is decreased, the cable secondary resistance, therefore length, may be increased.
4. The energy (joules) put into the weld zone of a short-time spot weld is only a small fraction of that used in making a conventional spot weld. This improved weld efficiency is attained partly because the weld nugget is thinner and mainly because waste heat leakage cannot spread during the short period. Heat leakage causes a great waste of welding energy within the weld zone.
5. Water cooling is eliminated because the short-time weld consumes less energy. With these short weld periods of 2 or 3 milliseconds, very little energy (compared with an a.-c. weld of several cycles) goes into heating of cables, tool and transformer.
6. Of the total energy spent in the circuit the energy that is delivered to the weld section is in direct proportion to the ratio of the resistance of the weld section to that of the equivalent total circuit resistance. Any effect of circuit inductance can be discounted in the foregoing consideration.
7. Limitation to shortening the weld time is imposed only by excessive current rates of rise that will produce surface fusion with excessive spot indentation and electrode wear.

Conclusions

The advantages of the Portable Discharge Welder are:

1. Only low power is demanded even with a fair welding speed of 30 welds per minute.
2. Combined weight lightness in machine, welding transformer and small size cables is utilized in a completely portable machine.
3. No water cooling is required.
4. The method of welding is completely portable, allowing the welding tool to be carried all over the assembly.
5. The equipment as a whole may be made self-sufficient and then requires only a source of fuel to furnish the power.
6. This equipment may be air borne.
7. If the portable welder is used on rural lines, the demand is low enough that bad voltage regulation will not result.
8. The energy required goes up roughly as the cube of the thickness so that the unit described has its best advantage in the light gages.

Some limitations considered are:

1. The weld nugget being thin, there is not the margin of safety between a normal energy weld and a low energy weld that the shot weld, whose nugget is thick, provides.
2. Heavy gages cannot be welded unless the whole welder design is drastically enlarged.
3. Surface spitting on gages of 0.035- and 0.040-in. stainless steel cause indentation and electrode wear.

Acknowledgment

The author wishes to thank Dr. C. A. Adams for his advice and valued assistance. The author also wishes to thank the E. G. Budd Manufacturing Co. for promoting this development and the following men for their contribution—J. R. Fetcher, H. Van Sciver, R. S. Phair and A. C. Johnson.

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Appendix 1

A normal simplification of the current and voltage equations is shown, the method being applied some time ago by Dr. Adams.

The solution for these equations would be extremely lengthy, and the reader is referred to the Bibliography for further reference to their origin. The equations and simplification are set down here.

Oscillatory Case $\frac{4L}{R^2C} > 1$

General Equations:

$$e_d = \frac{2E\sqrt{LC}}{\sqrt{4LC - R^2C^2}} \cdot \epsilon^{-\frac{Rt}{2L}} \cdot \sin\left(\frac{\sqrt{4LC - R^2C^2}}{2LC} \cdot t + \tan^{-1}\frac{\sqrt{4LC - R^2C^2}}{RC}\right) \quad (10)$$

$$i_d = \frac{-2CE}{\sqrt{4LC - R^2C^2}} \cdot \epsilon^{-\frac{Rt}{2L}} \cdot \sin\frac{\sqrt{4LC - R^2C^2}}{2LC} \cdot t \quad (11)$$

To simplify let

$$a = \frac{R}{2L} \quad (12)$$

$$n = \sqrt{\frac{4L}{R^2C} - 1} = \sqrt{\frac{2}{RaC} - 1} \quad (13)$$

Simplified Equations:

$$e_d = \frac{2E}{nR}\sqrt{\frac{L}{C}} \cdot \epsilon^{-at} \cdot \sin(ant + \tan^{-1}n) \quad (14)$$

$$i_d = \frac{-2E}{nR} \cdot \epsilon^{-at} \cdot \sin(ant) \quad (15)$$

Aside from the simplification obtained from Equations 12 and 13, the terms a and n are useful criteria.

Other useful values are:

$$\text{Time to first current zero} = \frac{\pi}{an} \quad (16)$$

$$\text{Approximation} = \pi\sqrt{LC}$$

$$\text{Time to first voltage zero} = \frac{\pi - \tan^{-1}n}{an} \quad (17)$$

Approximation—see Equation 30.

Also refer to Equations 32 and 33.

Critical Case $\frac{4L}{R_2C} = 1$

General Equations:

$$e_d = E\left(1 + \frac{Rt}{2L}\right)\epsilon^{-\frac{Rt}{2L}} \quad (18)$$

$$i = -\frac{E}{L} \cdot t \cdot \epsilon^{-\frac{Rt}{2L}} \quad (19)$$

To simplify (also refer to Equations 34 and 35)

$$e = E(1 + at)\epsilon^{-at} \quad (20)$$

$$i = -\frac{E}{L} \cdot t \cdot \epsilon^{-at} \quad (21)$$

where

$$a = \frac{R}{2L} \text{ (Equation 12)}$$

Logarithmic Case $\frac{4L}{R^2C} < 1$

General Equations:

$$e_d = \frac{E}{2}\left(\frac{RC}{\sqrt{R^2C^2 - 4LC}} + 1\right)\epsilon^{-\frac{t}{T_1}} - \frac{E}{2}\left(\frac{RC}{\sqrt{R^2C^2 - 4LC}} - 1\right)\epsilon^{-\frac{t}{T_2}} \quad (22)$$

$$i_d = \frac{CE}{\sqrt{R^2C^2 - 4LC}}\left(\epsilon^{-\frac{t}{T_1}} - \epsilon^{-\frac{t}{T_2}}\right) \quad (23)$$

where

$$T_1 = \frac{2LC}{RC - \sqrt{R^2C^2 - 4LC}} \quad (24)$$

$$T_2 = \frac{2LC}{RC + \sqrt{R^2C^2 - 4LC}} \quad (25)$$

To simplify let

$$m = \sqrt{1 - \frac{4L}{R^2C}} = \sqrt{1 - \frac{2}{RaC}} \quad (26)$$

Simplified Equations:

$$e_d = \frac{E}{2}\left(\frac{1}{m} + 1\right)\epsilon^{-at(1-m)} - \frac{E}{2}\left(\frac{1}{m} - 1\right)\epsilon^{-at(1+m)} \quad (27)$$

$$i_d = \frac{E}{mR}\left(\epsilon^{-at(1-m)} - \epsilon^{-at(1+m)}\right) \quad (28)$$

The simplification can be carried on further to obtain quite readily the peak current and time to peak (see Appendix 3).

Appendix 2

The welding transformer is the vital part of any capacitor discharge welder, and while this short reference section will not give full engineering design, certain considerations especially relating to the portable welder transformer should be of interest.

Those aspects considered vital are listed:

1. The transformer ratio (T) will normally be chosen as high as permits sufficient useful welding current flow for the particular welding circuit and the kind of welding involved. Thus, higher cable resistance and inductance may necessitate a lower ratio (see Fig. 13).
2. The transformer resistance must be minimized and will be governed by the design consideration of: (1) permissible temperature rise for the maximum duty cycle, (2) required circuit efficiency and (3) maximum allowable weight.
3. Reversal of the welding current flow with each discharge augments transformer output considerably because an appreciable residual flux is present and will be doubly lost if not taken advantage of.
4. Transformer flux leakage will tend to lower the current but will affect the energy only as it redistributes energy with respect to time. Leakage should be kept as low as possible in the design of the transformer.
5. To prevent saturation the flux should not range above the knee of the *B-H* curve until the completion of the useful current discharge interval and in no case before peak current is reached. It will be shown later that the total flux will be proportional to the integral of the net voltage discharge curve after deducting *IR* drop all with respect to time. Therefore, other things being equal, the longer the discharge the larger must be the core cross section or the number of primary turns, and the transformer size will increase accordingly. Saturation causes loss of secondary current magnitude.

Transformer saturation discussion now follows. Since weight economy dictates a close design, saturation is prevented both by current reversal through the transformer each time, and by a suitable *NS* product, i.e.,

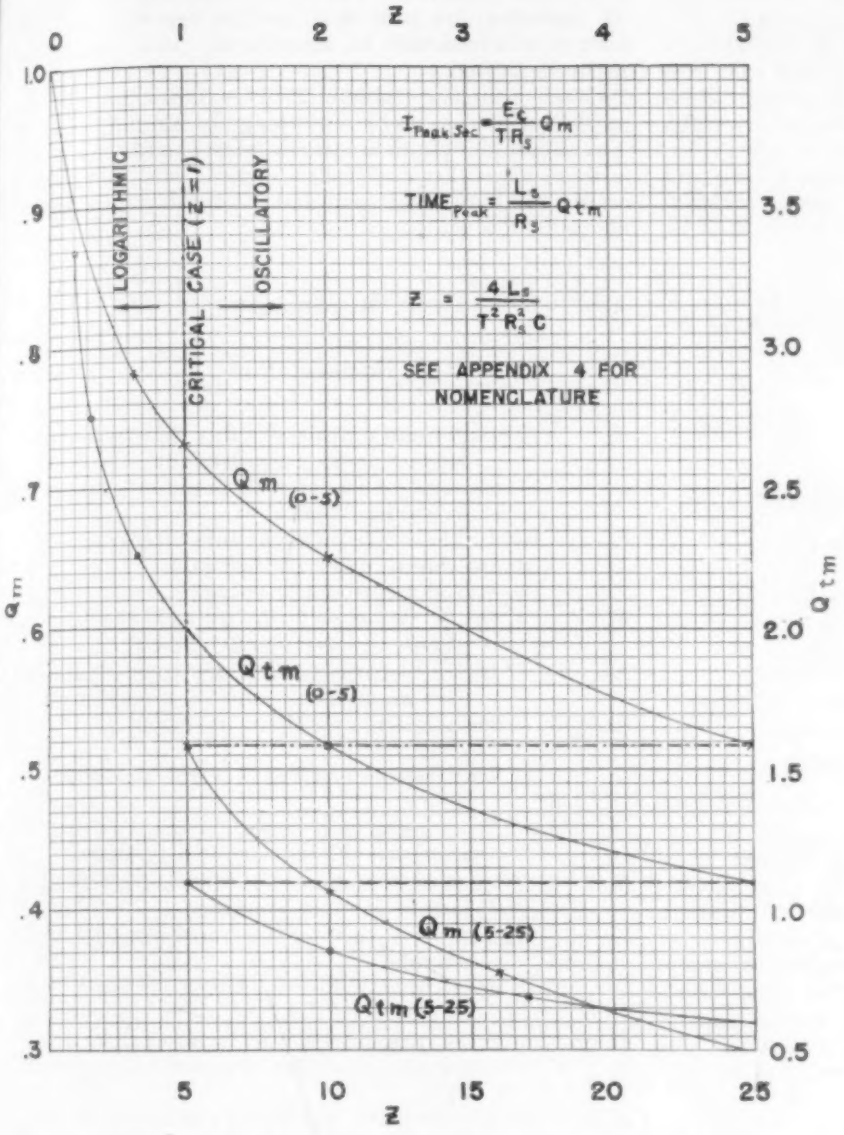


Fig. 13—Graph of Peak Secondary Current and Time to Peak

primary turns by core cross section. The N_pS product is derived.

Voltage induced in the primary turns:

$$e_f = -N_p \frac{d}{dt}\varphi\ 10^{-8}$$

whence

$$N_p\varphi = -10^8 \int_{t_1}^{t_2} e_f dt$$

Since

$$\varphi = BS$$

$$N_pS = \frac{-10^8}{B_m} \int_{t_1}^{t_2} e_f dt \qquad (29)$$

But N_pS is a product of the primary turns of the transformer and its cross section. Also the integral between limits t_1 and t_2 represents the area of the net discharge voltage curve. Hence, design precaution against saturation need consider (1) the required N_pS product, (2) the area of the net voltage discharge curve $(e_d - ir)$ out to the time where useful current ends (Fig. 7), (3) the maximum permissible flux density of the transformer iron and (4) current reversal.

Time to first voltage zero (osc. case) $= \dfrac{\pi - \tan^{-1}n}{an}$

(see Equation 17)

For a fairly oscillatory discharge

$n = \sqrt{\dfrac{4L}{R^2C} - 1}$ approximates $\sqrt{\dfrac{4L}{R^2C}}$

Time to first voltage zero then approximates

$$(\pi - \tan^{-1}n)\sqrt{LC} \qquad (30)$$

But L properly taken in terms of secondary circuit causes Equation 30 to become:

Approximate time to first voltage zero (osc. case) =

$$T(\pi - \tan^{-1}n)\sqrt{L_sC} \qquad (31)$$

The Equation 31 brings out that if the ratio (T) is doubled the flux will be approximately doubled. However, this can be readily handled if the primary is built with more than one coil, paralleling for low ratios and connecting in series for high ratios. N_p will increase with the higher ratios to maintain the correct N_pS product. It can further be shown that the transformer resistance under this design maintains the same percentage to the rest of the circuit, since doubling the ratio would increase the actual primary resistance four times, but its effect reflected into the secondary circuit would be but one-quarter of the former value. Any reasonable number of primary coils and ratios may be utilized in this manner by proper design of insulation and method of connecting the coils. Referring to the two voltage curves in Fig. 10, some idea of the flux increase is apparent for (T) increased four times.

The voltage area may be obtained graphically by substituting an equivalent triangle for the voltage discharge curve $(e_d - ir)$ letting the "hills equal the fills" as in area *abcd* (see Fig. 7, critical case)

It might seem paradoxical that the net area of the voltage time curve will become smaller if saturation does occur. However, analyzing this we will recall that the primary magnetizing current to produce flux must increase greatly under saturation, and the increased IR drop will obviously decrease the net induced voltage area. Thus, one test for saturation is to note whether the transformer primary or secondary voltage crosses zero at an earlier instant as the capacitor stored voltage is increased from a low value to the highest value. The oscillograph is required to make this test.

The foregoing covers some of the main factors that should be considered for the portable welder transformer design where weight is of prime importance. However, it may also apply to any discharge welding transformer design.

Appendix 3

There follows a ready method for obtaining the peak

weld current and time to peak based on plotting the log and/or sine terms for values relating to term $4L/R^2C$ of the main radical n (oscillatory case) or m (logarithmic case). The time-saving value of this method can best be appreciated by comparing it with the straight computation of the equations in the original form (Appendix 1).

The equations, obtained from Equations 15, 19 and 28 after differentiating for time to maximum, were used to plot Fig. 13. They are as follows:

Oscillatory Case

$$\text{Peak weld current} = \frac{2E}{TR_s n} \cdot \epsilon^{\frac{\tan^{-1} n}{n}} \cdot \sin \tan^{-1} n \qquad (32)$$

$$\text{Time to peak} = \frac{\tan^{-1} n}{an} \qquad (33)$$

Refer to Equations 7, 12 and 13 for T, a and n.

n becomes (instead of Equation 13)

$$n = \sqrt{\frac{4Ls}{T^2R_s^2C} - 1}$$

Critical Case

$$\text{Peak weld current} = \frac{0.732E}{TR_s} \qquad (34)$$

$$\text{Time to peak} = \frac{1}{a} \qquad (35)$$

Logarithmic Case

$$\text{Peak weld current} = \frac{E}{TR_s m}(k_1 - k_2) \qquad (36)$$

where

$$k_1 = \left[\frac{1+m}{1-m}\right]^{-\left(\frac{1-m}{2m}\right)} \qquad (37)$$

$$k_2 = \left[\frac{1+m}{1-m}\right]^{-\left(\frac{1+m}{2m}\right)} \qquad (38)$$

$$\text{Time to peak} = \frac{1}{2am} \log \epsilon \left(\frac{1+m}{1-m}\right) \qquad (39)$$

m becomes (instead of Equation 26)

$$m = \sqrt{1 - \frac{4L_s}{T^2R_s^2C}}$$

All values of circuit resistance and inductance are first summated in terms of the secondary, using equivalent values. Thus:

$$R_{sec.} = \frac{r_{pri.\ cable}}{T^2} + \frac{r_{Tr\ pri.}}{T^2} + r_{Tr\ sec.} + r_{sec.\ cable} + r_{tool} + r_{weld} \qquad (40)$$

The inductance in terms of secondary may be obtained in the same manner. For ratios (T) above 50/1 the effect of primary resistance and inductance is usually so small that it may justifiably be neglected. However, all transformer copper loss has been accounted for in (40). Likewise, hysteresis and eddy current transformer losses may be estimated as a factor Ktr, or can usually be neglected because small. A special factor K_{sat} would be required for increased energy dissipation if transformer saturation occurred. Thus, the ideal Equations 32 to 39, inclusive, are subject to certain practical reduction factors which should be considered, even though normally neglected.

Good accuracy (about 2%) is possible from this method with reasonable knowledge of circuit constants. The use of the graph is clearly defined, and the coverage is from logarithmic, through critical, and to a medium oscillatory case limit (suitable for most welding equipments).

Appendix 4

Nomenclature

B_m = maximum permissible flux density for transformer under consideration
C = capacity considered in terms of primary side of welder—farads
E = total voltage on capacitors after charge
I = maximum value of current
J = stored electrostatic energy—joules
K_{tr} = factor to correct for transformer core loss when calculating peak current
K_{sat} = factor to correct for transformer core saturation when calculating peak current
L_p or L = inductance of welder in terms of primary—henry
L_s = inductance of welder in terms of secondary—henry
L_{tp} = inductance of transformer primary
L_{ts} = inductance of transformer secondary
N_p = number of turns of the coils across the transformer primary winding
N_s = number of turns of the transformer secondary winding
Q = total final value of charge on capacitors—coulombs
R_p or R = resistance of welder in terms of primary
R_s = resistance of welder in terms of secondary—ohms
R_{tp} = resistance of transformer primary winding
R_{ts} = resistance of transformer secondary winding
S = cross section of welding transformer core
T = ratio of transformer primary turns over secondary turns. With subscript, T refers to logarithmic discharge time constant
a = simplification term that is reciprocal of critical case time constant
e_c = instantaneous voltage across capacitors during charge
e_d or e = instantaneous voltage across capacitors during discharge
e_f = voltage induced in transformer primary during capacitor discharge
i_c = instantaneous current during charge
i_d or i = instantaneous current in primary during discharge
k_1, k_2 = logarithmic discharge peak value terms
m = logarithmic equation simplification term
n = oscillatory equation simplification term
q = charge in a condenser at any given instant
t = passage of time during history of an event—seconds. May be conveniently expressed in milliseconds
ϵ = Naperian logarithm base = 2.71828
φ = Flux in welding transformer core

Routine Inspection and Salvage of Machinery Weldments*

(Rough, Partially Machined and Machined)

By James W. Owens†

Introduction

Scope of the Paper

In a paper on "Methods Improvement from the Viewpoint of Management,"‡ presented before the semiannual meeting of The American Society of Mechanical Engineers in Pittsburgh in June, Mr. J. K. Louden made the following two pertinent statements for consideration of the postwar manufacturer: that ". . . if we [as a company or a plant] are going to survive as an industrial unit, we must constantly increase our productivity and lower our costs" and that "accordingly we must embrace a program of cost reduction through waste elimination that calls for the united energies of our management, labor and technical team."

The writer unreservedly accepts these conclusions and adds that much of this waste elimination will depend on inspection and the use of materials and processes which facilitate salvage. This paper, therefore, considers the subject of routine inspection and salvage of machinery weldments in a large organization having shops for the machining of weldments fabricated in its weldries and by its subcontractors. These weldments are of two types:

(*a*) Those fabricated to customer specifications and designated "Customer Inspected."

(*b*) Those fabricated to the company's specifications, as stock items, and designated "Non-Customer Inspected."

In practice, the only difference between these two types of weldments is the necessity for facilitating Customer Inspection, keeping their inspectors informed of errors and defects and securing their approval of recommended salvage procedures by Salvage Requests.§

In this organization, the Inspection Department is independent of the Engineering and Production Departments, the Chief Inspector reporting direct to the Assistant General Manager. On inspection and salvage problems, involving welding and allied processes, the chief engineer of the Division and the Director of Welding function in an advisory capacity. The weight given to their opinions, individually or collectively, is dependent on the problem involved.

The fundamental information obtained from two researches, conducted by the author, one on Inspection and the other on Salvage, has been put into practical use and incorporated in the subject matter of this paper. These researches are, respectively:

(*a*) An investigation to determine the relative effectiveness and utility of direct current and alternating current for the Magnaflux inspection of fusion welds; also for the detection of laminations and segregations in plain carbon steels.

(*b*) An investigation on the Precision Welding of plain carbon steels.

Objectives of the Paper

As defective material will be found and errors will be made by workmen in all stages of weldment fabrication and processing, inspection is intimately bound up with both waste and salvage. This is particularly true of medium carbon steel weldments as compared with iron and steel castings in view of the fact that the possibility of salvaging weldments is infinitely greater, regardless of their state of completion. Because of this, the techniques and procedures involved in the inspection and salvage of weldments must be regarded by management as of major economic importance if the potential advantages of weldments over castings, including lower costs, are to be realized and made the most of.

Again, inspection methods and procedures which have been found necessary and have proved satisfactory for one type of product might be absolutely unnecessary and unsatisfactory for another type of product. This paper, therefore, has *three objectives*, each of which is considered in a separate section. These objectives are:

Objective No. 1.—To illustrate, by contrast, the necessity for an open-minded approach in the inspection and salvage of weldments in order to eliminate waste.

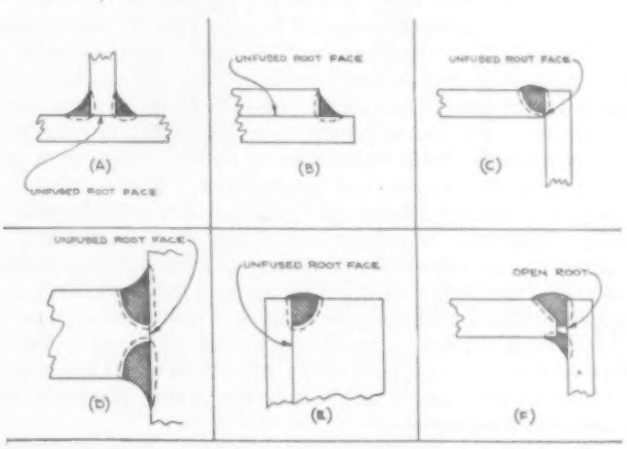


Fig. 1—Typical Joints and Welds Specifically Designed for Metal Arc Welding with Unfused Root Faces and/or Open Roots

* To be presented at the Twenty-Fifth Annual Meeting, A.W.S., Cleveland, Ohio, Oct. 16 to 19, 1944.

† Director of Welding, Fairbanks, Morse & Co., Beloit, Wis.

‡ *Mechanical Engineering*, July 1944.

§ See "Objectives and Uses of Salvage Requests" (SR's) p. 904.

Table 1—A Contrast of Design, Inspection and Salvage Requirements and Procedures

	(A) Boilers and Unfired Pressure Vessels		(B) Diesel Engine Block Weldments
1A	Major strength welds must be of the butt type.	1B	Major strength welds can invariably be of the fillet type.
2A	Unit working stresses of butt joints are usually the same as the base metal, consequently sound butt welds of 100% penetration are required.	2B	Joint efficiencies of 15% above the yield point of the base metal are in most cases entirely satisfactory.
3A	Shrinkage is usually not a major fabrication problem, because dimensional accuracy is, in general, not a factor.	3B	Shrinkage is usually a major problem because machining tolerances frequently require dimensional accuracy in every plane and several locations in the same plane.
4A	In view of 3A, open butt joints are usually not objectionable. There can also be a fair latitude in fit-up, provided roundness is not sacrificed.	4B	In view of 3B, open butt joints are not only decidedly objectionable but closed joints with wide root faces (or their equivalent) are essential for good fit-up.
5A	Radiographic inspection is desirable to insure that consistently sound welds are obtained with 100% penetration.	5B	Radiographic inspection is usually not necessary as fillet welds of not more than 2 layers are invariably required, and such welds can be made consistently sound within the required factors of safety.
6A	Interpretation of weld soundness, by d.-c. magnaflux inspection, is not hampered by patterns of open roots or unfused root faces as this type of subsurface discontinuity is not supposed to be present.	6B	Interpretation of weld soundness by d.-c. magnaflux inspection may be seriously hampered by unfused root faces as economical design invariably requires the incorporation of this type of subsurface discontinuity in the weldment.
7A	Magnaflux inspection, when used should preferably be of the d.-c. type (if butt welds are involved), to facilitate the detection of all types of subsurface defects.	7B	Magnaflux inspection, when used, should preferably be of the a.-c. type (when fillet welds are involved), otherwise inspection for weld soundness is severely hampered by subsurface discontinuities specifically incorporated in the design and for which neither material nor workmanship is responsible.
8A	As abrupt intersections of two or more planes can usually be avoided, cracks from residual and/or reaction stresses are, in general, not a serious problem except in way of manhole reinforcements.	8B	As the intersection of members in two or more planes cannot, in general, be avoided, cracks from residual and/or reaction stresses may be a problem.
9A	Incentive systems of payment may appreciably increase the tendency for defective workmanship when multiple layer manual butt welds are employed.	9B	Incentive systems of payment may actually decrease the tendency for defective workmanship when fillet-welded joints are used as the operator tends to work within the higher current range in order to increase the amount of work accomplished and therefore insures the proper amount of root penetration.
10A	Because of the linear simplicity of the structure, automatic welding can usually be extensively used. Furthermore it is advantageous because of 9A.	10B	Automatic welding is, in general, impractical to any great extent because of the complexity of the structure.
11A	There should not be any necessity for major salvage operations in any stage of fabrication.	11B	Because of the many surfaces which are machined to extremely close tolerances and the resulting machining errors, their salvage requires an engineering approval and an appreciable amount of skill and judgment.
12A	A hydrostatic test is required.	12B	A hydrostatic test is only required for air, oil and water passages when incorporated in the weldment.
13A	Weld spatter is primarily removed for appearance.	13B	Weld spatter, steel shot, mill scale and other foreign matter must be thoroughly removed to avoid clogging of lines, scoring of bearings, etc.

Objective No. 2.—To outline inspection methods and procedures which have been evolved to obtain the maximum economic advantages for machinery weldments.

Objective No. 3.—To outline salvage methods and procedures for partially and completely machined weldments which are technically, practically and economically sound.

Section 1—A Contrast of Design, Inspection and Salvage Requirements and Procedures

As boilers, unfired pressure vessels and Diesel engines are classified as "machinery," and as the inspectors of welded boilers and unfired pressure vessels may be called upon to inspect Diesel-engine block weldments and their auxiliary parts, these products will be used to illustrate the potentially wide variations in design, inspection and salvage requirements and procedures. This contrast is not only strikingly shown in Table 1, but this table graphically illustrates the desirability for the insertion of a clause in specifications governing inspection pointing out the desirability and/or necessity for inspectors seeking individual and collective advice from those capable of furnishing it before rendering decisions, so as to be assured that all available facts are known. This would include inspectors of the Customer when products are Customer Inspected.

"Salvage Committees" consisting of representatives from the inspection departments and the engineering divisions involved have been and are being satisfactorily used by the Company for minor nonrepetitive defects. However, for repetitive defects and defects beyond the scope of these committees, the use of the Salvage Requests, previously referred to, have been found necessary and have proved entirely satisfactory. On Customer Inspected products, these Requests are addressed to the Customer's Representative via the Company's Chief Inspector, and on "Non-Customer Inspected," they are addressed to the Company's Chief Inspector.

Section 2—Inspection Techniques and Procedures

Definitions

Lamination.—An actual physical discontinuity in the material.

Segregation.—A layer of different chemical composition than the metal on each side of it and wherein there is no *physical discontinuity* between this layer and the metal on each side of it.

Inspection of Templates, Dies and Fixtures

Inspection of weldments starts at the templates and dies for the "details," and at the fixtures for "subassemblies" and "final assemblies" so as to be assured of their accuracy before their use in routine production. Each is checked by flame cutting, forming, assembling and/or welding at least one "piece." If found correct, the template, die or fixture is steel stamped by an inspector.

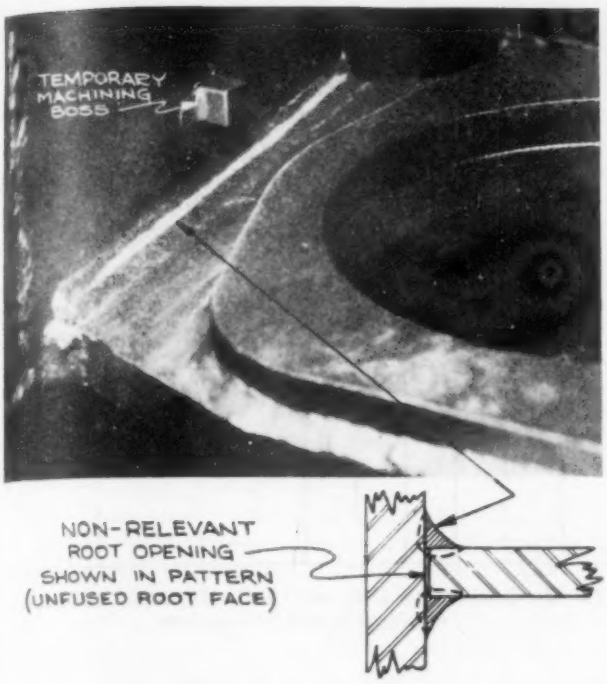


Fig. 2—D.-C. Magnaflux Pattern of a Nonrelevant Root Opening in a Fillet-Welded T Joint (No Pattern with A. C.)

Inspection of Base Metal

Certified mill reports of each heat are accepted by our Company for all low and medium carbon steels. However, the chemical analyses and physical properties of the base metals used in weldments, which are subject to heat treatments (other than stress relieving), are obtained under routine laboratory procedures. In products, or parts of products, wherein laminations in the completed weldment are prohibited by specification, a routine magnaflux inspection of all edges is undertaken after all shaping and forming operations on the details have been completed and prior to their use in subassemblies and assemblies. Localized laminations are completely melted and/or chipped out and welded as a routine operation. If the lamination is extensive, the inspector's attention is called to it for a decision as to whether the laminated section should be removed and a new section welded in its place or whether the part should be scrapped. The major point to be borne in mind is that this magnaflux inspection of detail parts can be quickly undertaken and minimizes expensive salvage operations or high scrap losses, should unacceptable laminations be discovered during or subsequent to machining. However, as laminations and segregations will occasionally be found during machining, their acceptability or unacceptability should be considered by inspection as wholly dependent on the product and their location in the product. In general, segregations are not objectionable in machinery weldments and two illustrations, Figs. 8 and 9, are

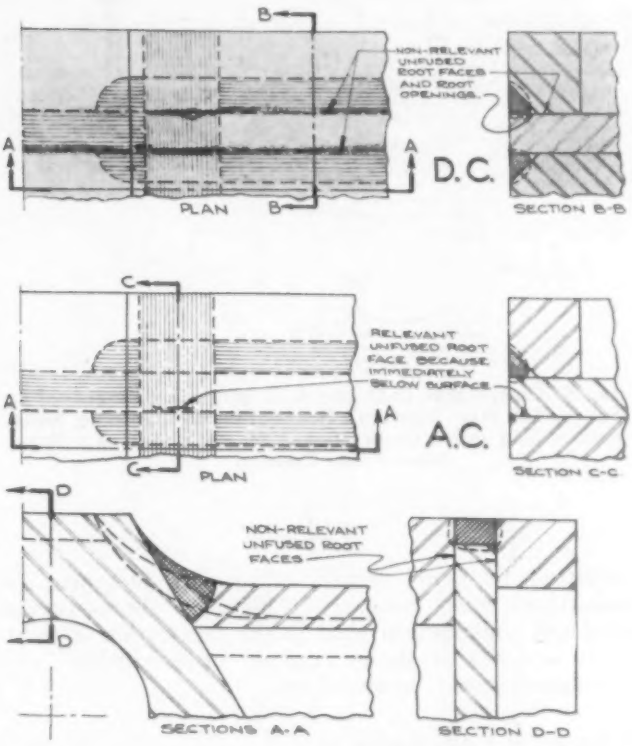


Fig. 3—Comparative D.-C. and A.-C. Magnaflux Patterns of Single Bevel and Square Butt Welds Showing Relevant and Nonrelevant Unfused Roots and/or Root Openings

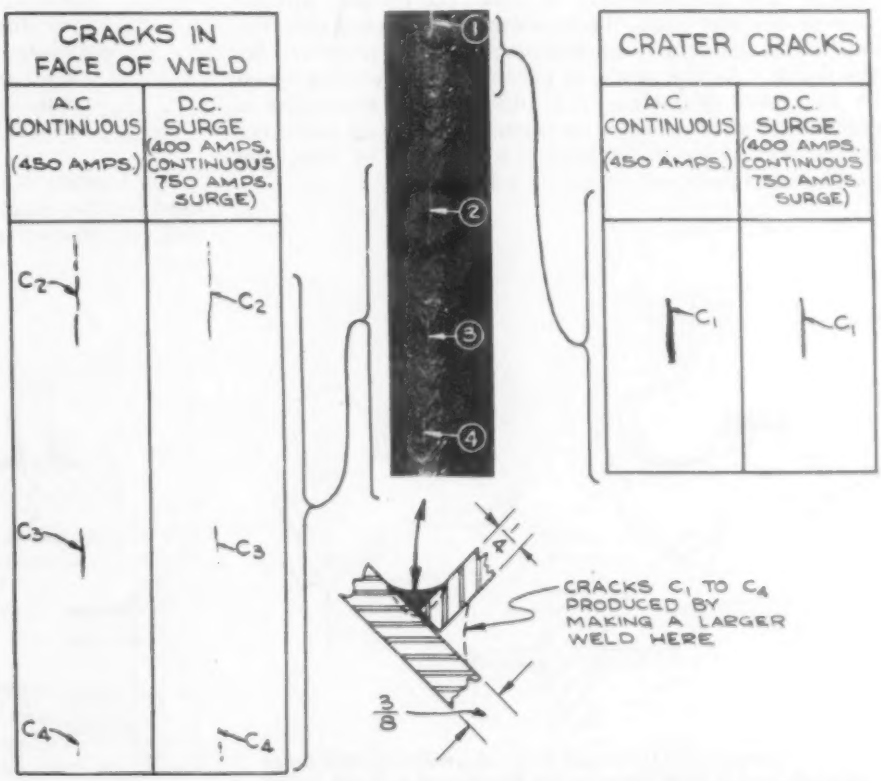


Fig. 4—Comparative D.-C and A.-C. Magnaflux Patterns of Cracks in the Face and Crater of a Fillet Weld

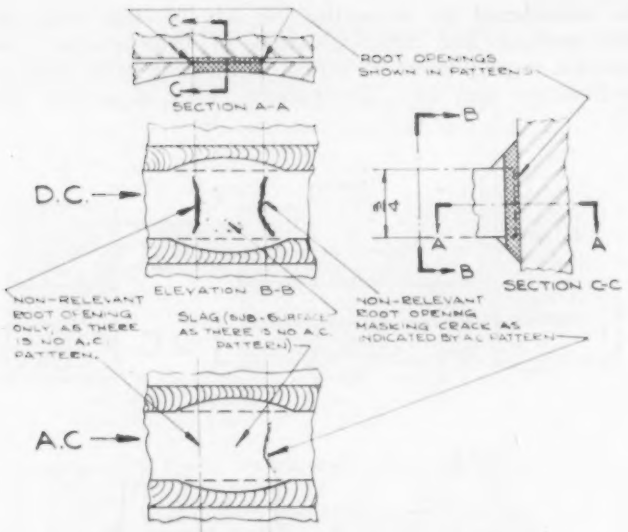


Fig. 5—Comparative D.-C. and A.-C. Magnaflux Patterns of a Square Butt Weld Showing a Nonrelevant Root Opening, Subsurface Slag and a Crack Masked by the Pattern of a Nonrelevant Root Opening

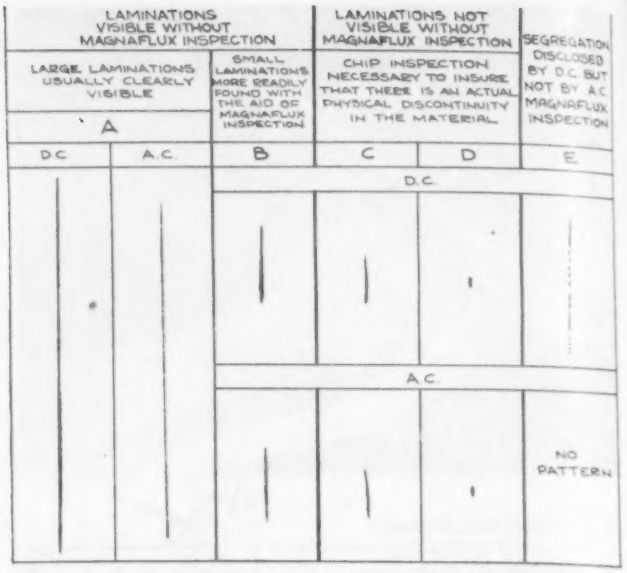


Fig. 7—Comparative D.-C. and A.-C. Magnaflux Patterns of Laminations and Segregations

submitted to assist inspectors to pass judgment on laminations when discovered. Figure 8 shows typical laminated construction used in the fabrication of weldments and Fig. 9 shows typical "objectionable" and "nonobjectionable" laminations.

Inspection of Flame Cutting

As the "grade of cut" can vary widely from that of a manual cut by an unskilled operator to that of a machine cut by a skilled operator, definite standards and procedures have been established to insure economic fabrication. By "grade of cut" is meant the relative squareness of the cut edge, its freedom from nicks, also the depth and uniformity of surface serrations produced by the flame. As the grade of cut is primarily determined by the speed of cutting, it is obvious that inspection is confronted with a major problem whenever an incentive system of payment is used. Regardless of this, the problem has been satisfactorily solved:

(*a*) By the preparation of standard sample cuts for the various "grades" and over the entire range of thicknesses normally used in production. The speeds of cutting, tip sizes and gas pressures are steel stamped on each sample. (See Table 2.)

(*b*) By conveniently locating these samples for the use of flame cutters, time study men, foremen and inspectors.

(*c*) By specifying the grade of cut required on the operation sheet.

(*d*) By prohibiting all grinding of flame-cut surfaces except those manually cut and exposed, or specifically called for on the drawing.

Grinding is generally considered to be a relatively cheap operation. However, it can easily become one of the most expensive operations when all factors are taken into consideration.

An A grade of cut is the best that can be made. It is used for the edges of members subject to fatigue stresses and for exposed edges in general. B and C grades of

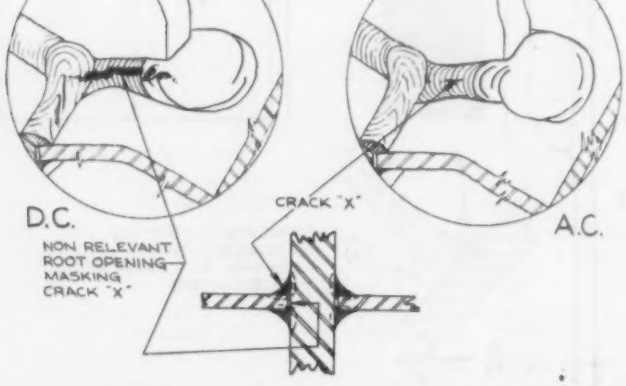


Fig. 6—Comparative D.-C. and A.-C. Magnaflux Patterns of a Fillet-Welded T Joint Showing the Masking of a Crack in the Face and Crater of a Fillet Weld by Its Nonrelevant Root Opening

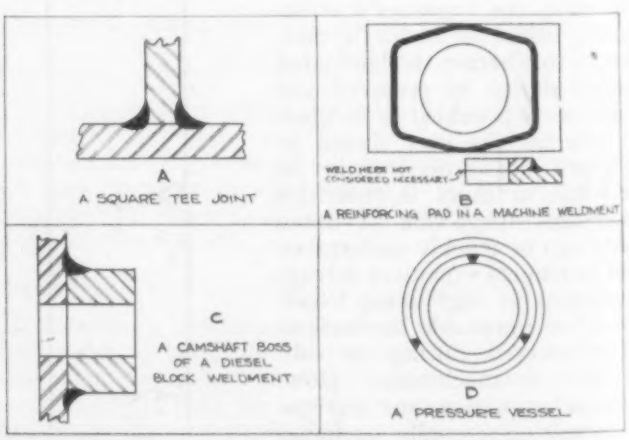


Fig. 8—Typical Laminated Construction Used in the Fabrication of Weldments

cuts are used principally for nonexposed or partially exposed surfaces, e.g., the root faces of tee joints, also for welded surfaces and surfaces to be machined. A study of Table 2 shows:

(*a*) That, in general, the speeds of machine flame cutting recommended by the manufacturers of these machines are too high for even the lowest grades of cutting required in machinery fabrication.

(*b*) That, the differences between the grades of cut vary appreciably over the entire range of thicknesses; as a result: In material over 4 in. in thickness, only Grade A cut is specified as Grades B and C would, in general, be unacceptable for any part of a machine, both from the standpoint of cost and serviceability. In material 1/4 to 3/8 in. and 1 5/8 to 4 in. in thickness, the A and C grades are specified as there is not enough difference between the A and B grades to justify the inclusion of both. In 1/2 to 1 1/2 in. material, all three grades are called for.

Salvage operators assigned to the repairing of flame-cut nicks are conveniently located to the flame-cutting and inspection departments. After the part has been flame cut, it is slagged with a pneumatic slagging hammer, inspected, salvaged if necessary and reinspected. These salvage operators are specially trained for this type of work. They should never be students or trainees, as improperly salvaged flame-cut scars can result in high scrap losses and very expensive salvage operations. The salvaging of the thrust-bearing saddle of a completely machined Diesel-engine block weldment (Figs. 18, 19, 20 and 21) is only one of hundreds of cases which can be cited by fabricators to prove this point.

Progressive Inspection of Assembling and Welding Operations

A progressive "dimensional" and "qualitative inspection" of the major operations involved in assembly and welding has been found to be necessary in the fabrication of the Company's Diesel-engine blocks. This procedure insures the early detection of defective workmanship and the placing of responsibility where it belongs. It also appreciably minimizes the likelihood that the part will ultimately be scrapped or salvaged.

In this inspection procedure, a printed form is used. On this form are listed all of the major production and inspection operations with spaces after each operation for initialing and dating on their completion by foremen and inspectors, respectively. This form constitutes not only a progressive record of all operations, but is used by the production department to chart the daily status of all blocks in production. On completion of a block, the form is filed by the inspection department.

Layout-Inspection

Layout-inspection is the major dimensional inspection operation in the Company's weldries. It requires an accurately machined layout table, small screw jacks for leveling purposes, surface blocks, surface gages and other precision tools.

White cold-water paint or a layout stain is freely used to facilitate the scribing of layout lines on the weldment. These lines are centerpunched at appropriate locations after all shifting has been completed and the layout operator is satisfied that the weldment will clean up when machined. Furthermore, to differentiate these centerpunch marks from all others, they are enclosed in an "o" stamp. All errors found in a layout-inspection are noted on appropriate routine forms and corrections made by the operators responsible or by operators assigned to the salvage department and specially trained to correct defects. These centerpunch marks are used by the machine operator to set up the weldment for machining. A welding layout-inspection should be accurate enough to eliminate the usual machine-shop layout.

Table 2—Recommended Speeds for the Various Grades of Machine Flame Cutting Required in Machinery Fabrication

(Data Given Is for Air Reduction Sales Co.'s Torches)

Plate Thickness, In.	Grade of Cut	Tip Size	Speed Inches per Min.	Gas Pressures (Lb./Sq. In.) Oxygen	Acetylene	Speeds Recommended by Manufacturer, In./Min.
(A) 1/4 to 3/8-In. Plates—Grades A and C Cuts						
1/4	A	0	19	20	2 1/2	20
	C	0	22	30	2 1/2	
5/16	A	1	19	20	2 1/2	Not given
	C	1	22	30	2 1/2	
3/8	A	1	17	20	2 1/2	19
	C	1	20	30	3	
(B) 1/2 to 1 1/2-In. Plates—Grades A, B and C Cuts						
	A	2	12	25	3	
1/2	B	2	14	30	3	17
	C	2	17	40	3	
	A	2	11	25	3	
5/8	B	2	14	30	3	Not given
	C	2	16	40	3	
	A	2	11	30	3	
3/4	B	2	13	36	3	15
	C	2	14 1/2	40	3	
	A	2	10	35	3	
7/8	B	2	12	40	3	Not given
	C	2	13 1/2	45	3	
	A	2	10	38	3	
1	B	2	12	42 1/2	3	14
	C	2	13 1/2	47 1/2	3	
	A	2	9	40	3	
1 1/8	B	2	10 1/2	45	3	Not given
	C	2	12	50	3	
	A	2	8	42 1/2	3	
1 1/4	B	2	9 1/2	47 1/2	3	Not given
	C	2	10 1/2	50	3	
	A	3	8	40	3	
1 3/8	B	3	9 1/2	45	3	Not given
	C	3	10	50	3	
	A	3	8	42 1/2	3	
1 1/2	B	3	9	47 1/2	3	12
	C	3	10	52 1/2	3	
(C) 1 5/8 to 1 1/2-In. Plates—Grades A and C Cuts						
1 5/8	A	3	7 1/2	45	3	Not given
	C	3	9	50	3	
1 3/4	A	4	7	45	3	Not given
	C	4	9	50	3	
2	A	4	6	45	3	10
	C	4	8	50	3	
2 1/4	A	4	5 1/2	45	3	Not given
	C	4	7	45	3	
2 1/2	A	4	5	45	3	Not given
	C	4	6 1/2	50	3	
2 3/4	A	5	5 1/2	45	3	Not given
	C	5	7 1/2	50	3	
3	A	5	5	45	4	8
	C	5	7	50	4	
3 1/4	A	5	5	45	4	Not given
	C	5	8	55	4	
3 1/2	A	5	5	45	4	Not given
	C	5	7 1/2	55	4	
4	A	6	6	60	5	7
	C	6	6	60	5	
(D) 4 1/2 to 6-In. Plates—Grade A Cut						
4 1/2	A	6	6	60	5	Not given
5	A	7	6	60	5	6
5 1/2	A	7	5	60	5	Not given
6	A	7	4	60	5	5

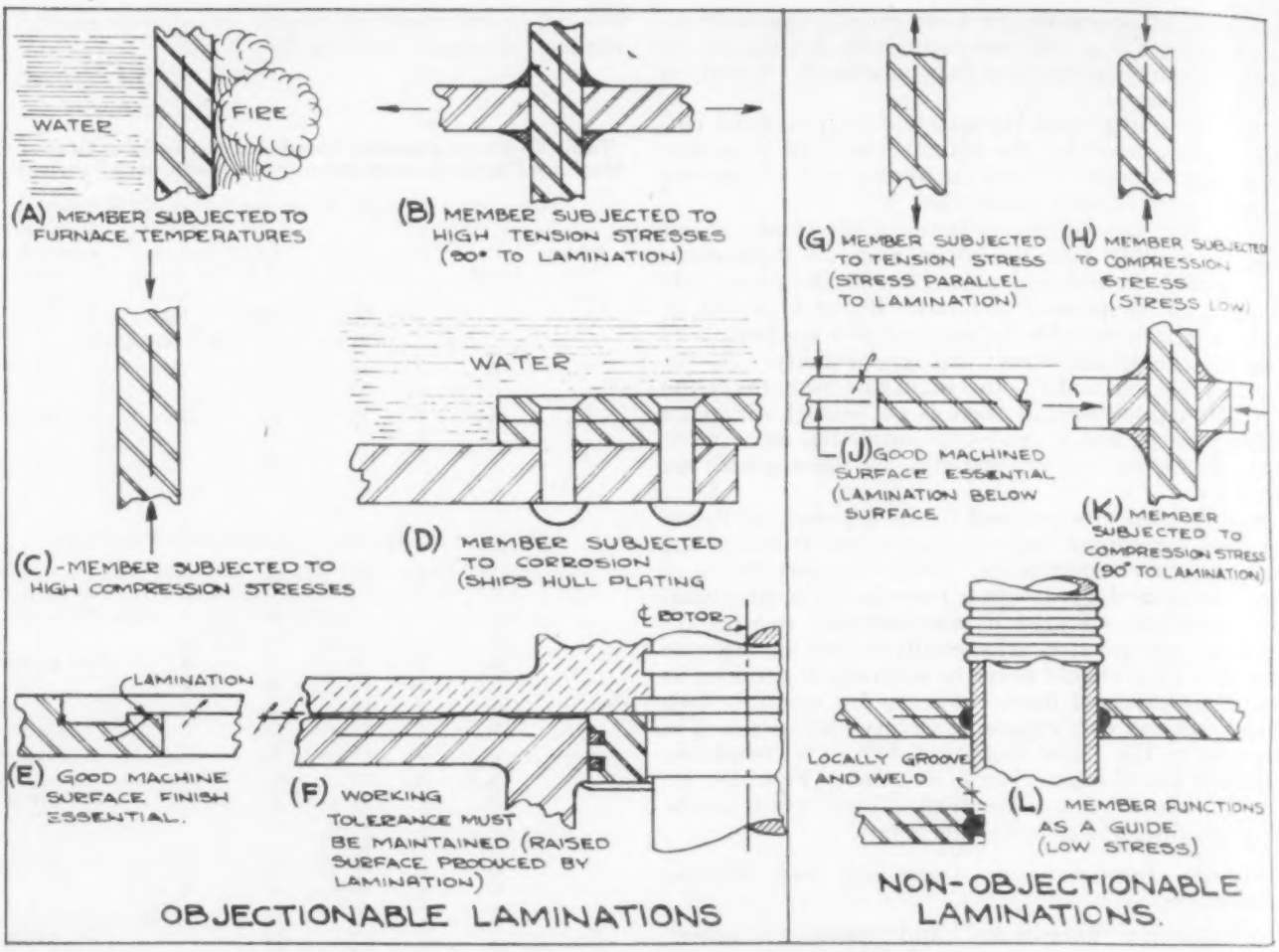

WATER
FIRE
(A) MEMBER SUBJECTED TO FURNACE TEMPERATURES
(B) MEMBER SUBJECTED TO HIGH TENSION STRESSES (90° TO LAMINATION)
(G) MEMBER SUBJECTED TO TENSION STRESS (STRESS PARALLEL TO LAMINATION)
(H) MEMBER SUBJECTED TO COMPRESSION STRESS (STRESS LOW)
WATER
(C) MEMBER SUBJECTED TO HIGH COMPRESSION STRESSES
(D) MEMBER SUBJECTED TO CORROSION (SHIPS HULL PLATING
(J) GOOD MACHINED SURFACE ESSENTIAL (LAMINATION BELOW SURFACE
(K) MEMBER SUBJECTED TO COMPRESSION STRESS (90° TO LAMINATION)
℄ ROTOR
LAMINATION
(E) GOOD MACHINE SURFACE FINISH ESSENTIAL.
(F) WORKING TOLERANCE MUST BE MAINTAINED (RAISED SURFACE PRODUCED BY LAMINATION)
LOCALLY GROOVE AND WELD
(L) MEMBER FUNCTIONS AS A GUIDE (LOW STRESS)
OBJECTIONABLE LAMINATIONS
NON-OBJECTIONABLE LAMINATIONS.

Fig. 9—Typical Objectionable and Nonobjectionable Laminations

Non-destructive Inspection Tests

The three outstanding and most widely used non-destructive inspection methods are:

(*a*) The gamma ray.
(*b*) The X-ray.
(*c*) Magnetic particle.

The first two methods are best adapted to fusion butt welds wherein a joint efficiency of 100% is required, whereas the latter is best adapted to all forms of fusion welds wherein neither the design nor the specification calls for complete root fusion.

Magnaflux Inspection for Cracks, Slag Inclusions, Laminations and Segregations

Magnetic particle inspection, commercially known as "Magnaflux inspection," is, in the author's opinion, of vastly more importance to the welding industry, as a whole than radiographic inspection on account of its simplicity of application, low cost and ability to ferret out and differentiate between cracks, laminations and segregations. Cracks (particularly surface cracks) are, in general, much more harmful to the serviceability of weldments than subsurface porosity. Furthermore, the class of electrodes now available, combined with welding operator qualification tests, has practically eliminated

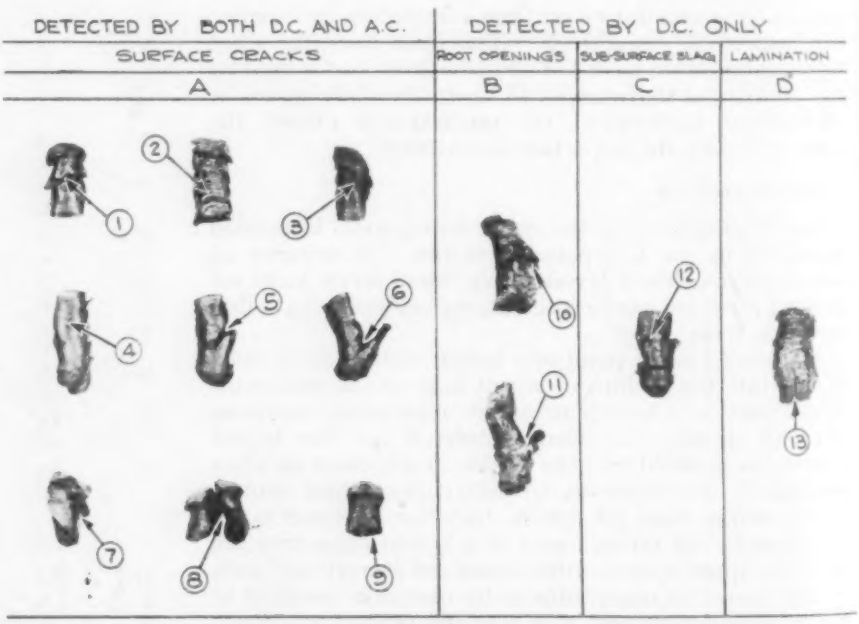


Fig. 10—Typical Surface Cracks, Root Openings and Subsurface Slag in Welds, Also Lamination on Plate Edge as Observed by Chip Inspection

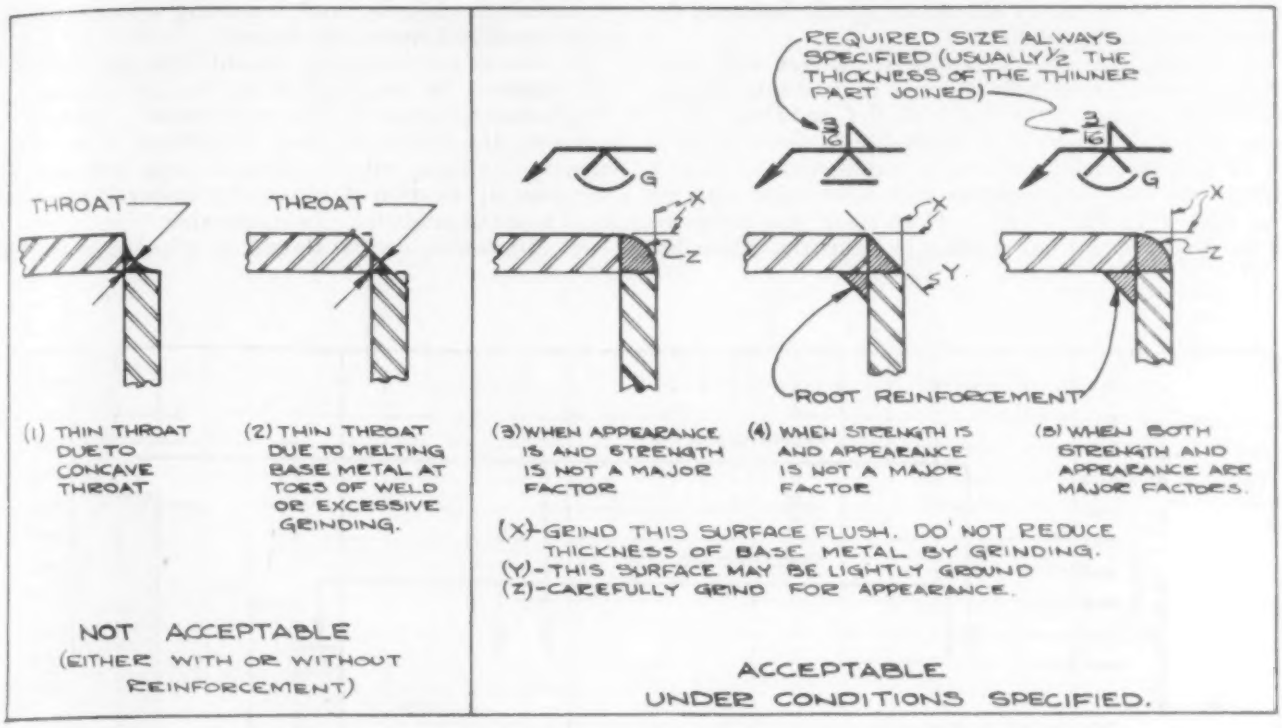

THROAT
THROAT
(1) THIN THROAT DUE TO CONCAVE THROAT
(2) THIN THROAT DUE TO MELTING BASE METAL AT TOES OF WELD OR EXCESSIVE GRINDING.
NOT ACCEPTABLE
(EITHER WITH OR WITHOUT REINFORCEMENT)
REQUIRED SIZE ALWAYS SPECIFIED (USUALLY 1/2 THE THICKNESS OF THE THINNER PART JOINED)
3/16
3/16
G
G
X
Z
X
Y
Z
ROOT REINFORCEMENT
(3) WHEN APPEARANCE IS AND STRENGTH IS NOT A MAJOR FACTOR
(4) WHEN STRENGTH IS AND APPEARANCE IS NOT A MAJOR FACTOR
(5) WHEN BOTH STRENGTH AND APPEARANCE ARE MAJOR FACTORS.
(X)-GRIND THIS SURFACE FLUSH. DO NOT REDUCE THICKNESS OF BASE METAL BY GRINDING.
(Y)-THIS SURFACE MAY BE LIGHTLY GROUND
(Z)-CAREFULLY GRIND FOR APPEARANCE.
ACCEPTABLE
UNDER CONDITIONS SPECIFIED.

Fig. 11—Requirements for Corner Weld Reinforcement and Grinding

porosity as an inspection problem. Unfortunately, Magnaflux inspection has either: (*a*) not received the recognition it deserves, due to the almost exclusive use of d.-c. equipment and the resulting problems of pattern interpretation, which have not been confined to any group of inspectors, or (*b*) it has been the victim of much unwarranted criticism, as a satisfactory inspection tool, because of this condition. In either case, the responsibility for this state of affairs is directly traceable to test departments which have: (*a*) overemphasized the harmfulness of porosity and other types of subsurface defects and (*b*) insisted on using the most sensitive method of Magnaflux inspection, even though, in practice, it worked to their disadvantage in the detection of surface cracks.

The author was so thoroughly convinced of this state of affairs that, with the assistance of the Magnaflux Corporation, he has investigated the comparative use of direct and alternating current equipment. In the investigation, the corporation assigned Mr. Carl R. Betz, one of its engineers, to act in an advisory capacity. Furthermore, the following conclusions and recommendations, based on this investigation, were checked by Dr. A. V. de Forest, president of the corporation:

1. Nonrelevant Root Openings and/or Unfused Root Faces.—Direct current, when used at the appropriate current, frequently discloses root openings and unfused root faces which are *characteristic of the design and definitely intended by the designer.* (See Figs. 1 to 6, inclusive.) On the other hand, root openings and unfused root faces are positively not disclosed by alternating current regardless of current density employed, unless they are *immediately* below the surface as shown in Fig. 3. In view of this, alternating current should preferably be used for the Magnaflux inspection of fillet welds in general. The disclosure of nonrelevant foot openings by direct current has caused the soundness of sound welds to be questioned and has resulted in extensive chipping and re-welding operations, high scrap losses and production delays.

2. Face and Crater Cracks.—Figure 4 shows that direct and alternating currents are equally effective in locating cracks in the faces and craters of welds in plain carbon steels, *provided* the d.-c. Magnaflux pattern (picture) is not masked by the pattern of an adjacent root opening or other subsurface discontinuity as shown in Figs. 5 and 6.

3. Subsurface Slag Inclusions.—This type of subsurface discontinuity is disclosed by direct current as shown

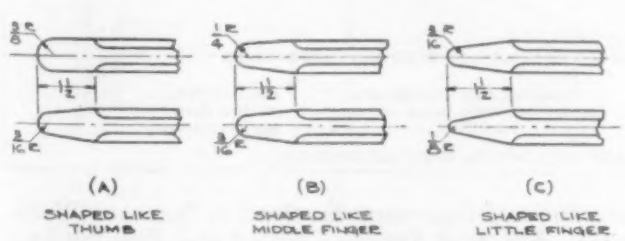


Fig. 12—Standard Points of Pneumatic Peening Chisels

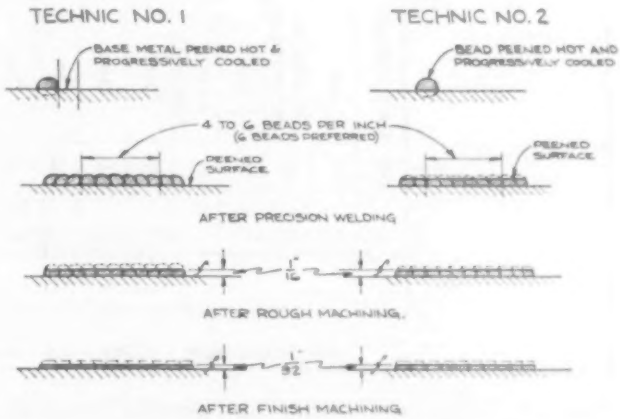

TECHNIC NO. 1
TECHNIC NO. 2
BASE METAL PEENED HOT & PROGRESSIVELY COOLED
BEAD PEENED HOT AND PROGRESSIVELY COOLED
4 TO 6 BEADS PER INCH (6 BEADS PREFERRED)
PEENED SURFACE
PEENED SURFACE
AFTER PRECISION WELDING
AFTER ROUGH MACHINING
AFTER FINISH MACHINING

Fig. 13—Sketch Showing Fundamental Technique for Precision Welding

in Fig. 5. Its relevancy should be wholly based on design and service requirements.

4. Laminations and Segregations.—Direct and alternating currents are equally effective in detecting laminations at plate edges. (See Fig. 7 (*A*, *B*, *C* and *D*).) However, alternating current is preferable to direct current for the production inspection of laminations, as direct current discloses segregations and alternating current does not. (See Fig. 7 (*E*).) Here again, the exclusive use of direct current has resulted in industrial waste due to extensive chipping and rewelding operations, high scrap losses and production delays.

In view of the foregoing, the author is convinced that this removal of uncertainty in the interpretation of Magnaflux patterns by the appropriate individual or combined use of d.-c. and a.-c. equipment, at equivalent current densities, will facilitate a more scientific and economic application of Magnaflux inspection to welds in all types of products. To summarize:

1. Alternating current should, in general, be used for

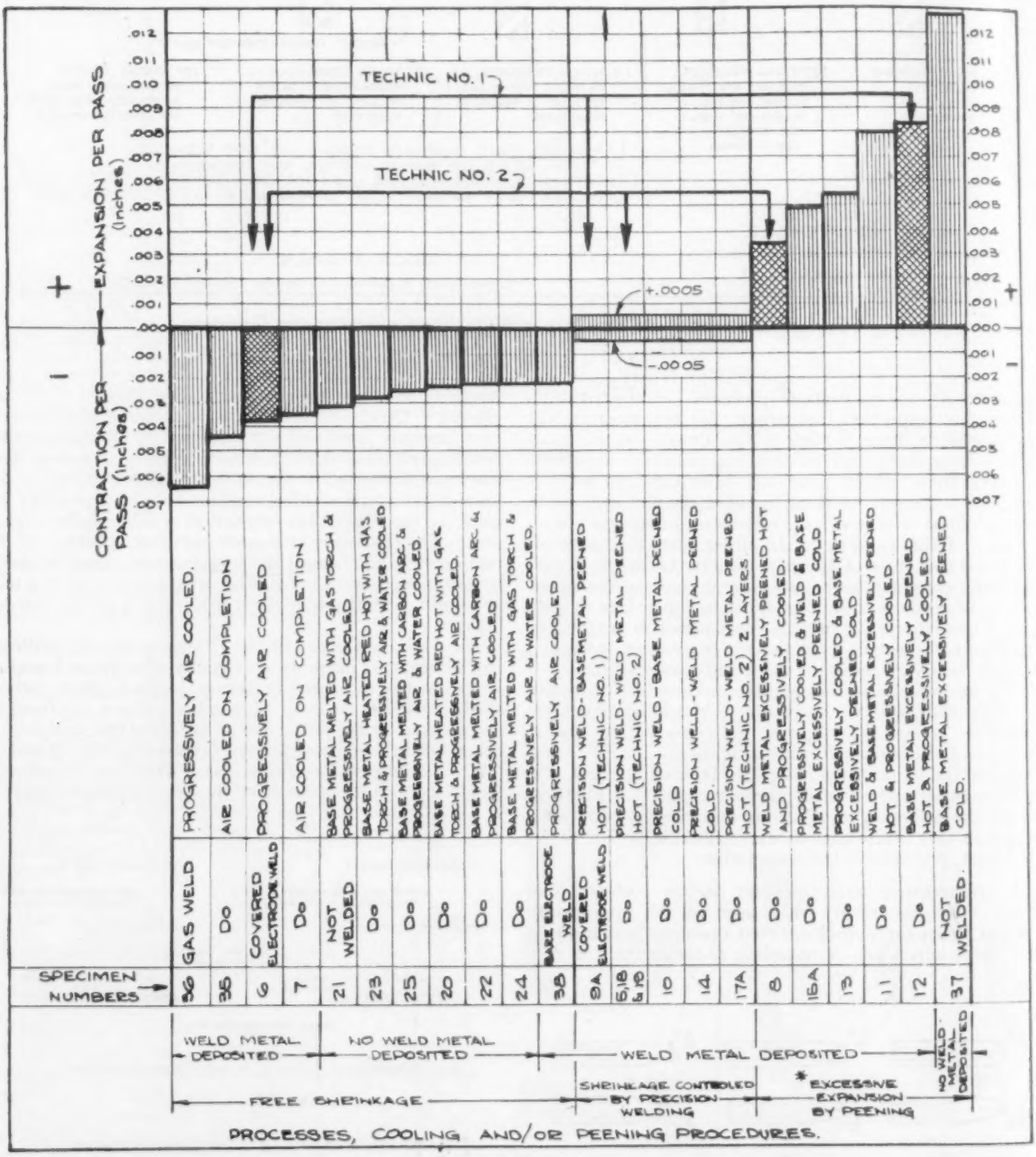


Fig. 14—Diagram Showing the Potential Range of Contraction and Expansion Involved in Precision Welding as Obtained by the Use of Different Thermal Processes, Also with Various Cooling and Peening Procedures

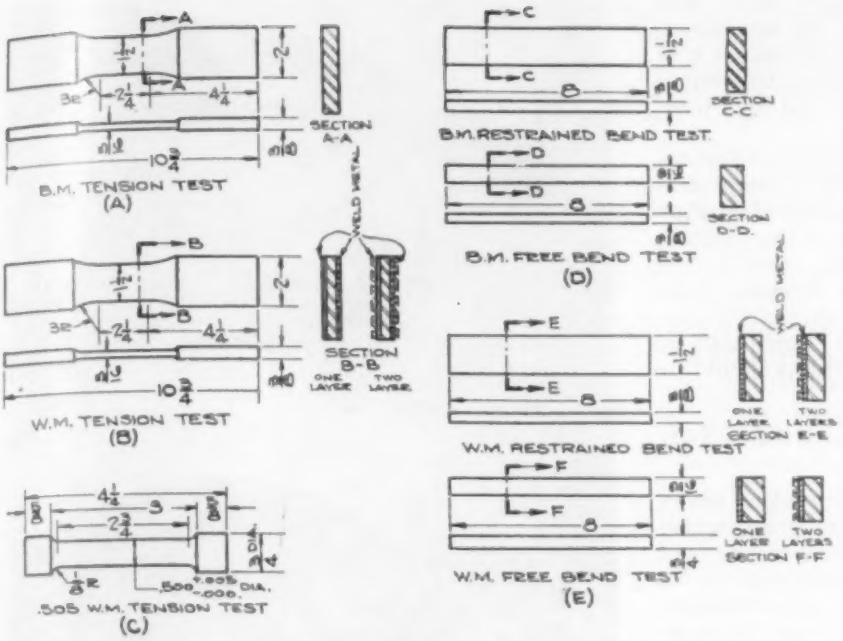


Fig. 15—Specimens Used for Physical Tests of Weld Metal Deposited by Precision Welding

the inspection of fillet welds, butt welds designed for partial penetration and for the inspection of plate edges for laminations.

2. *Direct current* should, in general, be used for the inspection of butt welds designed for 100% penetration and a relatively high freedom from porosity.

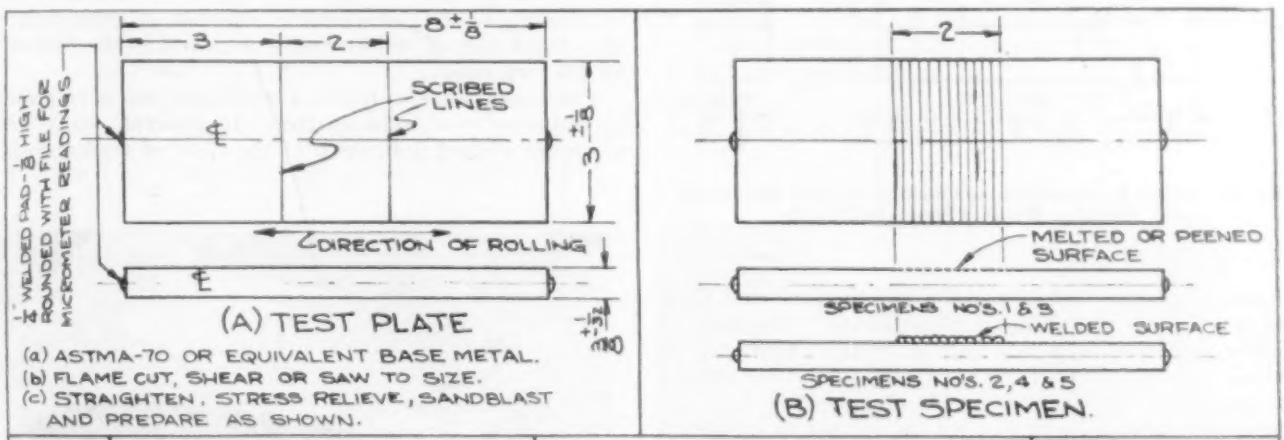
The following should also be borne in mind when using Magnaflux inspection:

1. To date it is impossible to completely eliminate fabrication cracks in the base metal, in welds and in weld craters at points of high-stress concentration such as manhole reinforcements, closing welds in large assemblies, the ends of gussets and in way of intersecting members. However, the author believes that the application of precision welding as outlined in the following section of this paper will go a long way in solving this problem.

2. Cracks will be found, after stress relieving, even though the product has been Magnaflux inspected before stress relieving and all observed cracks chipped out, rewelded and Re-Magnafluxed.

3. All locations, subject to high static, dynamic and/or fatigue stresses in service, should be investigated for cracks by Magnaflux inspection. If the product is stress relieved, an investigation should be made both before and after stress relieving.

4. It is essential that a routine Magnaflux inspection procedure be used which involves the recording of all


SCRIBED LINES
DIRECTION OF ROLLING
WELDED PAD - HIGH ROUNDED WITH FILE FOR MICROMETER READINGS
(A) TEST PLATE
(a) ASTMA-70 OR EQUIVALENT BASE METAL.
(b) FLAME CUT, SHEAR OR SAW TO SIZE.
(c) STRAIGHTEN, STRESS RELIEVE, SANDBLAST AND PREPARE AS SHOWN.
MELTED OR PEENED SURFACE
SPECIMENS NO'S. 1 & 3
WELDED SURFACE
SPECIMENS NO'S. 2, 4 & 5
(B) TEST SPECIMEN.

TEST SPEC. NO.	PROCEDURE	OBJECTIVES	(2) FINAL SHRINKAGE OR EXPANSION EXPECTED.
1(1)	PROGRESSIVELY MELT THE BASE METAL WITH OXY-ACET. FLAME & AIR QUENCH	TO ILLUSTRATE THE QUANTATIVE SHRINKAGE DUE TO THE MELTING OF THE BASE METAL AND AIR QUENCHING.	-0.025 to -0.035
2(1)	PROGRESSIVELY MELT THE BASE METAL WITH CARBON ARC AND AIR QUENCH.		-0.020 TO -0.030
3	PROGRESSIVELY WELD WITH COVERED ELECTRODE AND AIR QUENCH	TO ILLUSTRATE THE QUANTATIVE SHRINKAGE DUE TO METAL ARC WELDING AND AIR QUENCHING.	-0.030 TO -0.040
4	PROGRESSIVELY AND EXCESSIVELY PEEN THE BASE METAL COLD.	TO ILLUSTRATE THE QUANTATIVE EFFECT OF EXPANSION DUE TO EXCESSIVE PEENING.	+0.180 TO +0.190
5	PRECISION WELD, USING TECHNIC NO. 1	TO ILLUSTRATE THE QUANTATIVE CONTROL OF WELDING SHRINKAGE WITH TWO TECHNICS	±0.0005
6	PRECISION WELD, USING TECHNIC NO. 2		

TECHNIC:—
(a)-SEE TEXT FOR FUNDAMENTAL TECHNIC.
(b)-SPECIMENS SHOULD BE PROGRESSIVELY AND CAREFULLY STRAIGHTENED IN A PRESS.
(c)-MICROMETER READINGS SHOULD BE TAKEN AFTER EACH BEAD (OR PASS) USING TYPE OF FORM DESCRIBED IN TEXT.

(1) ONE OF THESE SPECIMENS SHOULD BE MADE IF EQUIPMENT IS AVAILABLE. IF OXY-ACETYLENE MELTING IS EMPLOYED USE A NO. 8 TIP (AIRCO). IF CARBON ARC MELTING IS EMPLOYED USE A ¼" CARBON AND APPROXIMATELY 105 AMPS. (2) - 12 PASSES AND/OR BEADS.

Fig. 16—Proposed Qualification Test Specimens for Precision Welding

cracks and their reinspection after repairs have been made. Such inspection procedures are not production handicaps for they ultimately result in decreased cost through the elimination of chipping, improved techniques for the reduction in the number of cracks and their complete elimination, in certain locations.

5. When specifications require that laminated material be kept out of a product, this can be accomplished in a relatively high degree through routine Magnaflux inspection of the part prior to its assembly in the product, using both direct current and alternating current. As previously pointed out, direct current discloses both laminations and segregations, whereas alternating current discloses only laminations. Should laminations be later found in the product, their harmfulness should be analyzed on the basis of Figs. 8 and 9.

Prohibition of Grinding and Peening of Weld Faces Prior to final Inspection

The remarks on the grinding of flame-cut edges, under "Inspection of Flame Cutting," are equally applicable to grinding and peening of weld faces prior to the final inspection of the weldment. The principal reasons for their general prohibition at this stage of fabrication are the impossibility of properly inspecting the faces

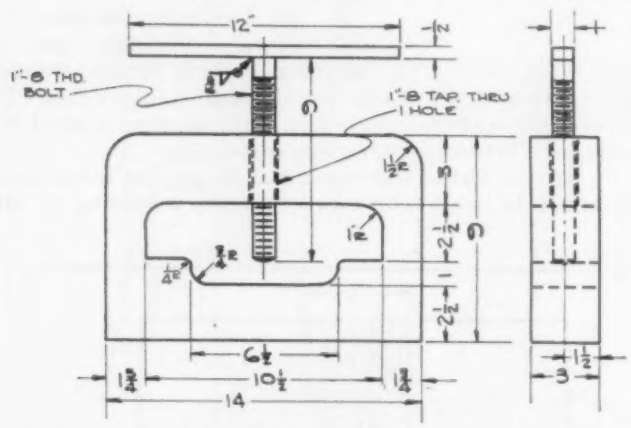


Fig. 17—Fixture for Straightening Qualification Test Specimens for Precision Welding Shown in Fig. 16

of welds if ground and/or peened and the fact that their use encourages defective workmanship. Grinding at this stage of weldment fabrication should, in general, be specially indicated by inspectors, and at no time should the peening of the faces of welds be sanctioned, except in a precision-welding procedure as outlined in Section 3. One of the few grinding exceptions is that of corner welds which should be a "must," provided the weld is reinforced at its root face or when appearance is the only reason for grinding and strength is not a factor. (See Fig. 11.) Unslightly corner welds can spoil the appearance of an otherwise excellent job.

Inspection of Cleaning Prior to Final Inspection

All weldments should be cleaned and the thoroughness required embodied in the specifications for the product. For example, foundry flasks would only require the removal of the slag from the welds to facilitate their inspection, whereas, in Diesel-engine fabrication, mill scale, weld spatter, sand, shot, grit and other foreign matter must be completely removed from all water, oil and air passages and surfaces, regardless of the procedure necessary to accomplish the results. This extreme care is necessary to avoid the scoring of bearings, the wrecking of pumps and physical damage to moving parts and sur-

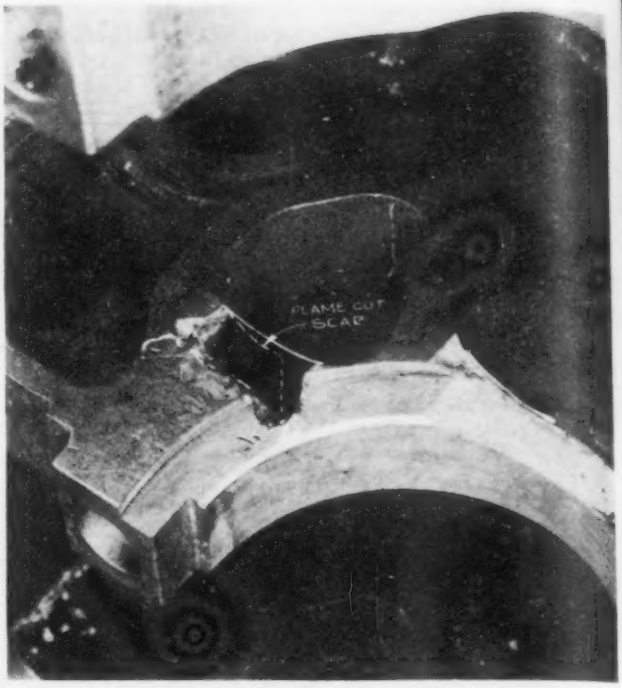


Fig. 18—Detail View of a Thrust-Bearing Saddle of a Completely Machined Diesel-Engine Block Weldment Showing a Defect Prepared for Precision Welding. (Repair Necessitated by an Incorrect Salvage Procedure of a Flame-Cutting Defect)

faces in general. Another requirement of importance in the fabrication of weldments for this type of product is the avoidance and removal of metal slivers on surfaces. Slivers catch lint causing the clogging of water, oil and air passages. A considerable amount of education in the cleanliness of weldments is required in the industry for its own good.

The appearance of many a weldment has been ruined by painting over weld spatter. In general, one is able to secure a good indication of the class of workmanship

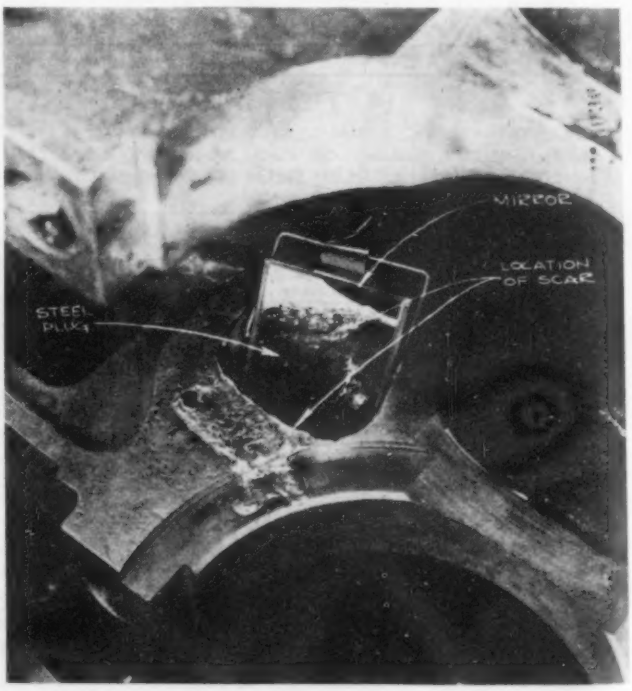


Fig. 19—Defect Shown in Fig. 18 After Precision Welding

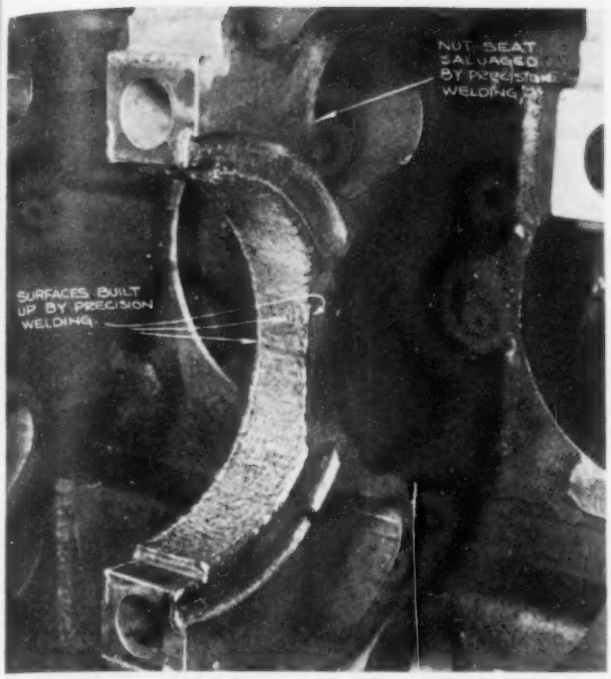


Fig. 20—Machined Surfaces of Thrust-Bearing Saddle Shown in Fig. 18 Built Up by Precision Welding

produced by an organization and its type of inspection by observing the cleanliness of its weldments.

Two cleaning methods have been found effective. The first method requires the use of a light pneumatic scaling hammer and a wire brush, usually referred to on drawings as "chisel and wire brush." The second method is "sand (shot) blasting" which should always be used when mill scale must be removed in addition to weld spatter. This latter method also requires the use of the pneumatic scaling hammer.

Section 3—Salvage Techniques and Procedures

Salvage of Partially and Completely Machined Weldments

Machinery weldments are invariably machined and are therefore stress relieved to insure the obtaining of the required machining tolerances. These tolerances will usually vary from ± 0.015 to ± 0.0005 in., depending on the product, also the location and function of the machined surface. Because of these close tolerances, it is usually inadvisable or impossible to use the welding process in the salvage of machined weldments unless: (*a*) the weld is in a location which would not change machining tolerances by shrinkage or by the introduction of residual and/or reaction stresses in the product; (*b*) precision welding can be employed to prevent shrinkage and avoid these stresses; or (*c*) the amount of welding can be appreciably reduced by making the repair primarily mechanical.

As an alternative, an inspector can approve a defective product "as is" if, in his judgment, the defect does not affect serviceability and/or interchangeability. The acceptance of laminations, under certain conditions and in certain locations, is a case in point. (See the previous section, including Figs. 7, 8 and 9.)

Definitions

Before describing in detail the technique of precision welding, as developed by the author, for the salvage of machinery weldments, it is essential that the following related terms be defined: melt, weldt, welding stress, restraining stress, residual stress, reaction stress, hot peening, cold peening and precision welding. The term weldt has been coined and the other definitions may not necessarily agree with those previously appearing in the publications of the SOCIETY.

Melt—Molten base metal.

Weldt—Molten base and filler metal, viz., molten "weld metal."

Welding stress—A stress, the forces of which have a thermal origin.

Restraining stress—The stress produced during welding by the expansion and concentration of metal contiguous to a melt and/or a weldt.

NOTE: The contraction produced by a "melt" which has cooled may or may not be less than that produced by a weldt of similar size which also has cooled. (See Fig. 14.)

Residual stress—Stress produced by thermal differentials or by mechanical treatment or both, during welding or other processing of the material. These are the stresses that remain after welding or other processing.

Reaction stress—The stress produced in a previously welded joint or previously welded structure, as a whole, by welding, temperature changes (atmospheric and furnace) and/or service stresses.

NOTE: The term reaction stress should, in the author's opinion, be *completely divorced* from the rigidity or fixity of the joint being welded, as there is no stress in the joint until the instant that the first increments of melt and/or weldt have frozen. The stress is then progressively increased by the cooled and cooling increments. The cooled increments can produce greater rigidity (fixity) than external restraint.

Hot peening—The mechanical stretching by hammering of base or weld metal before they have cooled to atmospheric temperature.

Cold peening—The mechanical stretching by hammering of base or weld metal at atmospheric temperature.

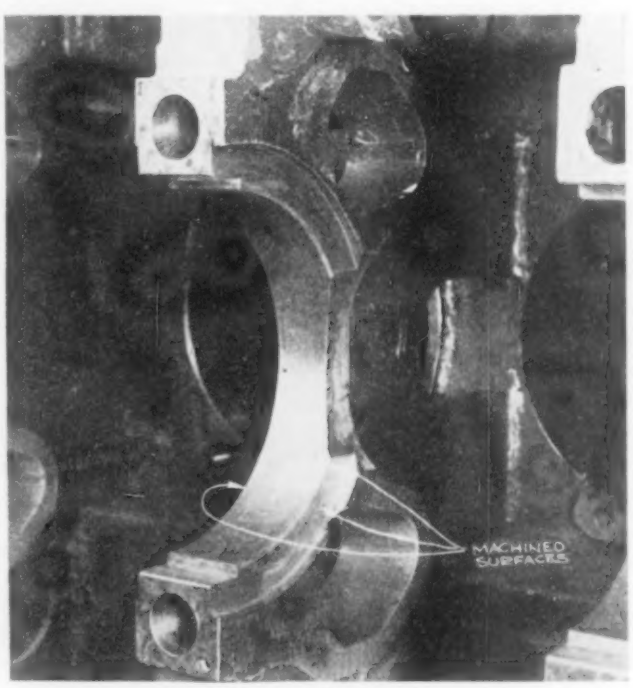


Fig. 21—Thrust-Bearing Saddle Shown in Fig. 20 After Machining

Precision welding—A metal arc welding process wherein shrinkage is quantitatively controlled.

Planning for Precision Welding

The quantitative control of shrinkage by precision welding is an operation requiring care and skill and must be carefully planned. Planning should include:

1. The procurement of the following tools:
   1—Wire brush.
   1—Manual slag hammer.
   1—Medium weight pneumatic hammer with a $1^1/_2$- to 2-in. stroke.
   3—Pneumatic chisels with points shaped like the end of a man's thumb, middle and little fingers. (See Fig. 12.)
   2—Air hoses in addition to the one attached to the pneumatic hammer.
   1 or more—Appropriate micrometers. Occasionally, also strain gages.
2. The furnishing of suitable printed forms for recording and controlling shrinkage by one or both of the two following precision welding techniques.

   Technique No. 1:

   (*a*) Take micrometer readings before welding.
   (*b*) Take micrometer readings after all of the following series of operations: the deposition of a weld bead, the hot peening of the base metal immediately adjacent to the bead and the cooling of both the the bead and the continguous base metal to the ambient temperature.
   (*c*) Obtain difference between readings (*a*) and (*b*).

   Technique No. 2:

   (*d*) Take micrometer readings before welding.
   (*e*) Take micrometer readings after all of the following operations: the deposition of each weld bead, the hot peening of each weld bead and the cooling of both the bead and contiguous base metal to the ambient temperature.
   (*f*) Obtain the difference between readings (*d*) and (*e*).

3. The selection and procuring of enough electrodes of the grades and sizes required.
4. The training and qualification of a welding operator, by means of the fundamental technique outlined in Fig. 13 and the qualification test outlined in Fig. 16.
5. On very important jobs, the procurement of a mechanic (preferably a machinist) to take, record and immediately calculate the micrometer readings, unless the welding operator is skilled in the use of precision tools.

Detail Description of Precision Welding

Up to May of this year, the author's practice always has been to hot peen the weld metal, and the base metal was only peened when it was also necessary to do so to secure the required tolerances.

At this time, an extensive investigation of precision welding was conducted which clearly indicated the feasibility and desirability of exclusively peening the base metal, either hot or cold. However, as hot peening was found to minimize the development of cracks, it has been adopted as standard practice in both Techniques Nos. 1 and 2. The results of these tests are briefly summarized

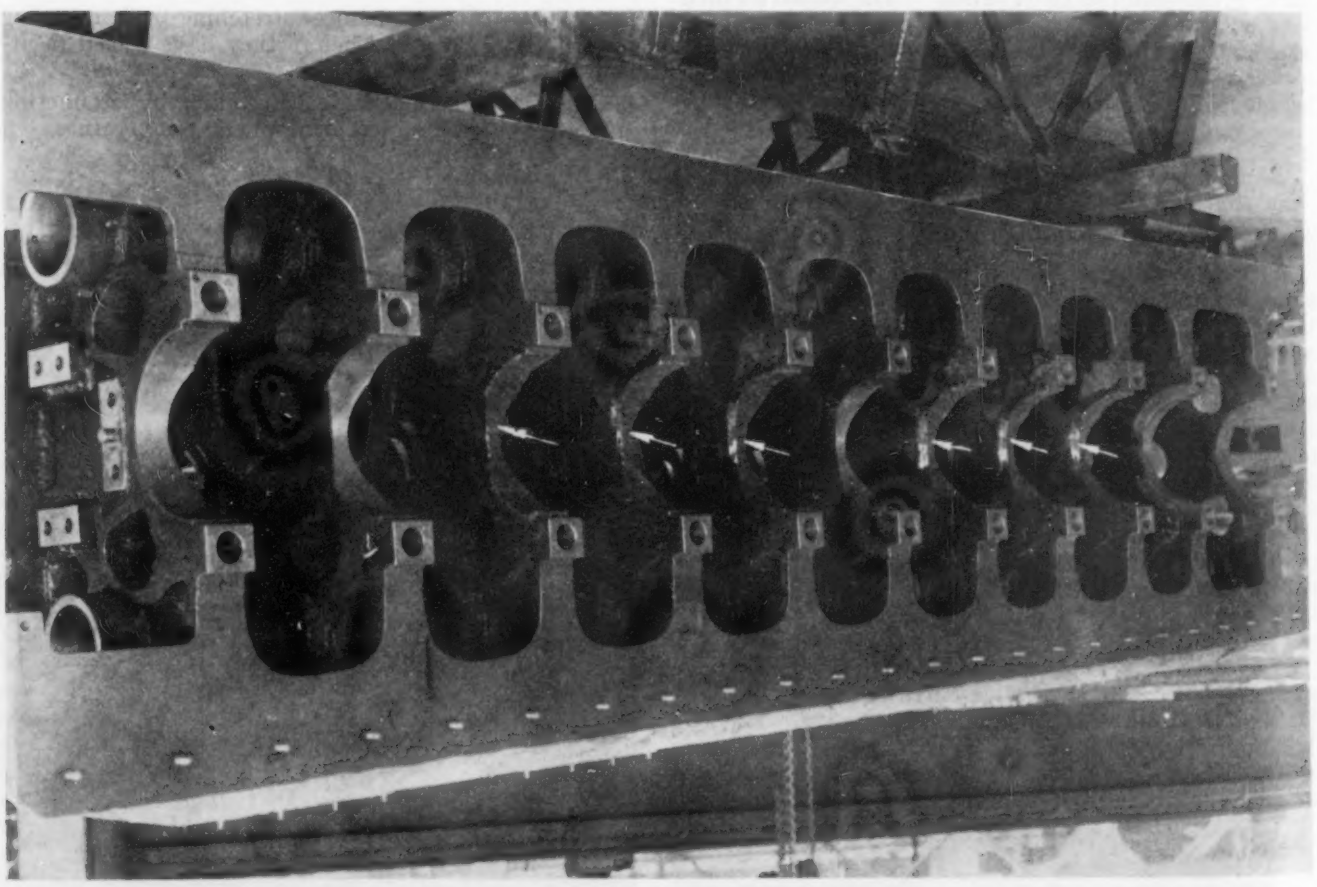


Fig. 22—View of a Completely Machined Diesel-Engine Block Weldment Showing Bores Which Were Machined Oversized and Salvaged by Precision Welding

Table 3—Physical Properties of Weld Metal Deposited by Precision Welding *Using Techniques Nos. 1 and 2

Test	Type of Specimen	Fig. No.	Technique	Ultimate Strength, Lb./Sq. In.	Yield Point Lb./Sq. In.	Elongation in 2 In., %	Restrained Bend, % Elongation	Free Bend, % Elongation
Tension	Base metal	15 (*A*)	.....	56,700	33,566	47.0	...	..
	Weld and base metal	15 (*B*)	No. 1 (1 layer)	73,500	55,860	28.0	...	..
			No. 2 (1 layer)	80,000	60,100	7.5	...	..
			No. 2 (2 layer) †	82,100	68,600	25.5	...	..
	All weld metal	15 (*C*)	No. 2 (multiple layer)	85,200	73,450	19.0	...	..
Bend	Base metal	15 (*D*)	.....	....	....	..	19.5	47.0
	Weld and base metal	15 (*E*)	No. 1 (1 layer)	....	....	..	20.3	43.7
			No. 2 (1 layer)	....	....	..	12.5	37.5
			No. 2 (2 layer)*	....	....	..	18.75	40.6

* Only one precision-welded specimen of each variable was tested. The data for the base metal specimens are the average of three specimens.

† Rarely used for machining defects. Improved ductility is due to the annealing of the first layer by the second layer which was completely removed in these two test specimens. Direct comparisons of the physical properties of the metal obtained with the two techniques apply only to one layer deposition.

in Fig. 14, Table 3 and in the text. The test specimens used for the physical tests of the weld metal deposited by precision welding are shown in Fig. 15.

The improved ductility of the metal in the precision welded area, as shown in Table 3, also the greater peening range with less peening, appeared so attractive that it was immediately applied in practice with complete success. This investigation also led to the development of the qualification tests outlined in Fig. 16 which, in its turn, will make possible vast economies in welded fabrication as compared with the unavoidable high scrap losses of castings due to defects discovered and errors made in the machine shop. As we are dealing with machinery weldments and as precision welding is primarily used in this type of fabrication to correct machining errors, a detail description of the process will be restricted to the building up of surfaces by one layer of weld metal. This description is as follows:

(*a*) Use A.W.S. $^1/_8$ in. E 6020 electrodes, at approximately 105 amp. and 4, 5 or 6 beads per inch (6 beads preferred).

(*b*) Use either Technique No. 1 or No. 2 depending on the physical properties of the metal desired in the salvaged area. Technique No. 1 is to be preferred if greater ductility is desired with a greater peening range and less peening, whereas Technique No. 2 should be used if higher yield and ultimate strengths, also harder metal, are wanted. (See Fig. 14 and Table 3). In any case always maintain (if possible) a positive tolerance of 0.002 to 0.003 in. throughout the entire salvage operation so as to be assured of final accuracy without the necessity of normal or excessive peening of the last bead or beads. If accurate control is once lost, it is very difficult, if not impossible, to regain it.

(*c*) Remove the slag from the bead with a manual scaling hammer immediately after its red color has disappeared. Sometimes a quick wirebrushing is also desirable.

(*d*) Immediately peen, using the technique specified.

(*e*) Turn the compressed air on the bead and contiguous parts of the structure, in full force, as soon as the base metal or bead has been peened enough. The completion of cooling should be judged by using the bare hand to compare the temperature of the area welded with the sections of the structure not affected by the welding heat.

(*f*) Do not restrain any part of the structure. Precision-welding is facilitated by a free movement of the part or parts welded, and these parts should be progressively measured so as to insure, if possible, the maintenance of their original dimensions.

Some Typical Salvage Operations Involving Precision Welding

The precision-welding process is being used by Fairbanks, Morse & Co. principally to build up bearing saddles and other parts of Diesel-engine block weldments and auxiliary parts which are found by the machine shop to be inaccurately located; accidentally scored, bored or faced oversize during machining; laminated; scarred by flame cutting or otherwise defective. It is also used for the salvage of completely or partially machined gray iron castings. Some of these salvage operations have required several days for their completion.

Figures 18, 19, 20 and 21 show the thrust-bearing saddle of a stress-relieved and completely machined ten-cylinder Diesel-engine block weldment wherein the nut seat, also the saddle and thrust bearing faces, were precision welded because of inaccuracies caused by the salvaging of a flame-cut scar in the location shown in Fig. 18. This weldment was once scrapped because the salvage operation described was considered impossible by the Company's Diesel Engineering Division and by both the Company's and a Customer's Inspection Department. Subsequent to salvaging, this block has for several months, been subjected to a severe overload test. To date there has been no indication of failure. It should be noted that Technique No. 2 was used as Technique No. 1 had not as yet been developed.

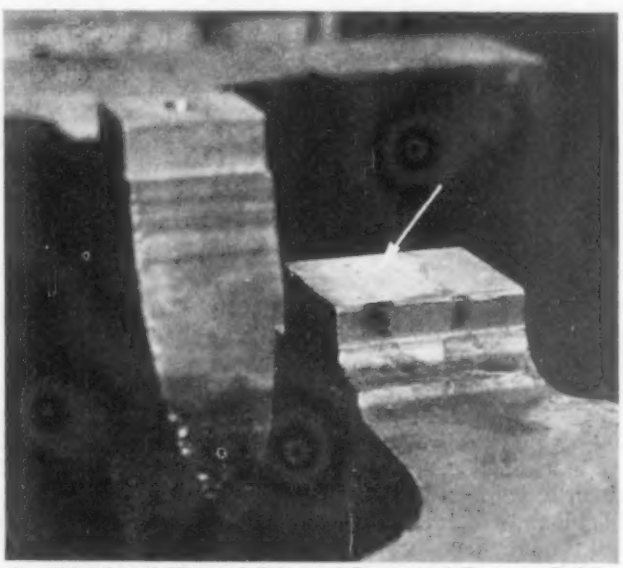


Fig. 23—Detail View of Salvaged Laminated Bearing Saddle Post, After Rough Machining

Figure 22 shows six lower bearing saddles of another stress-relieved and completely machined block weldment which have been salvaged by precision welding on account of being bored oversize.

Figure 23 shows the salvaging by precision welding of a laminated bearing saddle post of a stress-relieved and partially machined, Diesel engine block weldment.

NOTE: In Figs. 21 and 22, tolerances across cap fits as close as ±0.0015 in. were obtained on the completion of welding.

Figure 24 shows the building up of a counterbored surface on an 11-in. diameter deck bore which was machined oversize. Maximum and minimum tolerances of −0.0043 and −0.0028 in., respectively, were obtained after 14 hrs. of work. These tolerances were for readings "A" and "B." During this time 20 beads approximately 3 in. long were deposited, peened and cooled and six independent micrometer readings made between the completion of one bead and the deposition of the next one. Four of the six readings were in the adjacent bores.

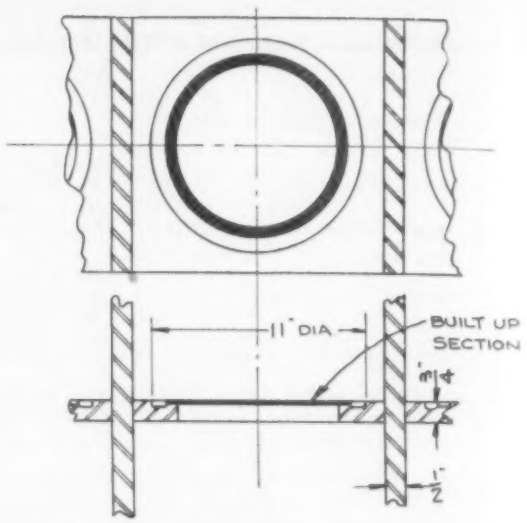


Fig. 24—Counterbored Surface of an 11-In. Diameter Deck Bore of a Completely Machined Diesel-Engine Block Weldment Which Was Built Up by Precision Welding

Other Salvage Methods

Bushings, pads and other shapes are resorted to and the parts held in place by welds of specified size and continuity when precision welding cannot be utilized because of inaccessibility of the area to be salvaged or because of the uncertainty of maintaining the necessary machining tolerances. The following should be noted in connection with the use of bushings:

(*a*) A normal press fit of 0.003 to 0.004 in. is, in general, all that is necessary to insure a metal-to-metal fit when bushings are held in place by strength welds.

(*b*) Strength welds are far more effective than press fits in maintaining a metal-to-metal contact in service.

(*c*) If bushings are of small cross section, press fits in excess of the amount specified may produce permanent sets and thus a loosening of the bushings. On the other hand, if bushings are of appreciable cross section, such fits may cause changes in the permissible tolerances of contiguous machined surfaces.

(*d*) In general, fillet welds should not be used which are smaller than the $^1/_4$ x $^3/_4$ in. or $^1/_4$ x 1 in. Furthermore, at least three or four should be specified.

(*e*) Special care should be taken to be assured that the welds are not reduced in size when the part is machined.

(*f*) Rings or bushings should be flame cut or otherwise obtained from solid stock, stress relieved, machined and inspected before being used.

Chrome plating can be advantageously and economically used for building up surfaces from which not more than 0.002 in. of metal has been removed and the parts can be physically handled in the plating tank. *Metal spraying* can be applied on gasket and press-fit surfaces when knurled grooves can be used to obtain a good bond and the end grooves can be located away from fillets so that they do not function as stress raisers.

Scrap Losses

Our Company's present high state of development of salvage technics and procedures, as applied to weldments, can best be illustrated by a reference to the scrap record on its $8^1/_8$ x 10 opposed piston Diesel engine blocks. On these weldments, there are approximately 5000 surfaces which are separately machined; yet to date, only one block has been scrapped out of a total of nearly 1800 which have been processed in the machine shop. Even this block, which was scrapped due to a machining error, could have been economically salvaged if a series of special exhaust belt decks were provided. It is at present being used for instruction purposes. Another interesting phase of this salvage procedure is the fact that, within the past year, it has rarely been found necessary to use mechanically attached parts in salvage operations.

If these blocks had been castings, many processing defects which are readily salvageable in machined weldments would have been jointly accepted by the engineering department, shop supervision and inspection. In addition, it is believed that the scrap loss due to machining errors and casting defects would have been at least 30%. On the other hand, the fact that weldments are more readily salvageable than castings makes it possible to abuse the process by salvaging errors and defects which cannot in any way affect the serviceability of the product.

It cannot be too strongly emphasized that the acceptance of salvage as a routine procedure in weldment fabrication, and the preparation and use of "Salvage Standards" (for those parts and locations which are subject to repetitive defects), does not necessarily condone or encourage defective workmanship, *provided* the responsibility for the defect is ferreted out and appropriate steps taken by management and supervision to prevent recurrence, in so far as it is humanly possible. Inspectors can render industry a real service by the fullest cooperation along these lines. This includes the planning, with supervision, of inspection and salvage procedures, to avoid the holding up of production which is often ruinously expensive due to idle time of labor and/or the tearing down of a setup and resetting up for machining. The use of precision welding as outlined herein greatly facilitates such cooperation on the part of inspectors as the actual procedure of salvaging can frequently be deferred until other operations have been completed.

Objectives and Uses of Salvage Requests

No detail of a salvage operation is left to chance on any of the Company's major products and "salvage standards" are also in use on repetitive defects in these products. As soon as a defect is discovered, a serially numbered "stop tag" with a correspondingly numbered "stub" is attached by an inspector of the Company to the defective part and a "PSR" (Preliminary Salvage Request) prepared in triplicate by the superintendent of the shop in which the defect is discovered.

The original copy of the PSR is forwarded, with the stub attached, to a Supervising Inspector specially assigned to salvage, the first carbon copy is placed in a

celluloid envelope attached to the defective material or part and the second carbon copy retained by the Superintendent. The information on the original copy of the PSR is used by the Supervising Inspector to prepare an "SR" (Salvage Request) in quadruplet, using a sketch whenever possible.

After appropriate approvals of the four copies of the SR have been obtained, they are distributed as follows:

Original Copy.—Customer's Representative or Company's Chief Inspector, depending on whether the job is "Customer Inspected" or a "Non-Customer Inspected."

First Carbon Copy.—The Company's Supervising Inspector involved.

Second Carbon Copy.—Superintendent involved for his information and use on shop floor in the salvage operation.

This copy replaces the first carbon copy of the PSR which had been attached to the detective material or part.

Third Carbon Copy. (with attached stop tag stub).—Shop Inspector (Customer or Company responsible for final approval).

If the job is customer inspected and the Customer's shop inspector is not posted on the proposed salvage operation, the defect is immediately identified by the number on the stop tag stub and investigated.

On completion of the Salvage operation, the following procedure is adhered to:

(*a*) The inspector (Customer or Company) holding the stop tag stub is notified by the foreman.

(*b*) The salvaged defect is then identified by this inspector by means of the stub number and inspected by him to insure compliance with the salvage specifications on the SR.

(*c*) If the salvage operation has been satisfactorily completed, the second carbon copy of the SR is initialed by the inspectors involved and forwarded to the Superintendent for his information and records.

(*d*) Appropriate steps are taken (disciplinary if necessary) by the Superintendent to prevent recurrence. In all cases, the cause of the defect, whether "material" or "workmanship," is noted on the PSR and the SR. If workmanship is involved, the name and clock number of the workman are recorded.

Copies of PSR and SR forms are locally provided with a carbon backing to facilitate their approval by the individuals involved.

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(*Continued on page 943*)

Evolution of Welding in Shipbuilding*

By M. N. Maltseff†

IN THE past three or four years, since the beginning the emergency Shipbuilding Program, a number of very good articles on Welding in Ship Construction have been presented to the industry. There were many papers clearly showing the advantage of welding, such as the simplicity of design, the saving of weight, the saving in labor and other numerous items. In the short space of three or four years, changes have taken place and developments gained through experience with this new, modern type of construction.

I would like to review this period and discuss some of the main points in the evolution of ship construction, from a welding standpoint.

No doubt you are familiar with some of the things I shall mention in this paper, either through your own experience or through reading similar articles. Some of the points that I may bring out may even seem radical, but it is my desire to call attention to them, having in mind that discussions may bring out some ideas that will improve the design of our future ships.

At the beginning of the emergency shipbuilding program, late in 1939, when the Maritime Commission had issued contracts for the construction of various sizes of C-type ships, only a few companies adopted a 100% welded type of construction. These companies had had a wealth of experience in welding, and had at least a nucleus of competent, welding-minded personnel. Needless to say, an undertaking of this nature, the welding of a hull structure 400 to 500 ft. long, offered a problem of considerable magnitude.

Looking back, I doubt if we would be using welding so extensively at the present time were it not for the fact that the progressive engineers of the Petroleum Industry, of many Municipalities and of Government agencies, such as the Bureau of Reclamation, had accepted welding as a method of construction of various refinery pressure vessels, pipe lines, penstocks, etc., long before welding was generally accepted as being more than just a mechanical process that could be used for repair jobs. We all remember that not long ago—say about 15 yr.—welding was hardly mentioned in the ASME Boiler Code, unless it was for some minor repair to boiler attachments. Now not only do we unhesitatingly tackle anything that adapts itself to welding, but we are actually looking for things which we believe could be constructed better and more economically by welding. There are many examples; for instance, pipe fittings, valves and manifolds, that were formerly cast, are now beautifully welded and at a saving in cost, not to mention a great number of other structures such as gears, gear casings, etc.

At this time I wish to mention that an undertaking of this size in time of emergency would not have been possible had there not been progressive and capable men at the head of the American Bureau of Shipping, the Maritime Commission, the Navy and the Army who had confidence and vision for the future of welded construction. They were certain that any obstacles would be overcome because they believed in the fundamental principles of welding.

Confidence in welding and its application to major structures was gained through the research work on the part of scientists and technical schools, who studied not only the metallurgy of welding, but also the behavior of welded joints under varying stresses. Research constantly is going forward and its findings are flowing in increasing volume into the hands of designers, detailers and welding engineers. Tremendous amounts of this engineering material will be available to all at the conclusion of the war. Much is being accomplished now that is not generally known, for obvious reasons, and welding is branching into so many fields of Engineering that each field eventually will present a lifetime study.

Very little, if any, help could be obtained from anyone as to construction and welding methods, equipment or organization, and there was a tremendous shortage of trained welding designers, detailers and supervisory personnel. So the construction of 100% welded ships of this size started, in most cases, with only the enthusiasm and firm belief of builders in welding, plus their ability and desire to work and produce something that was, up to this time, only a dream.

Emergency yards, due to the lack of experienced shipbuilders in their organizations, had to bring in old timers, either from retirement or from established shipyards, and forge them quickly into an organization charged with the responsibility of building modern vessels.

Needless to say, thoughts regarding the methods of construction and assembly of the ship varied greatly. Old-time shipbuilders were influenced by riveted construction of the hull, and, in general, were skeptical about new construction methods.

Traditions of building riveted ships prevailed throughout. It was extremely difficult to transform old ideas overnight. The ideas of old-time shipfitters did not properly fit into welded construction, where tolerances, shrinkages, warpages, locked-up stresses, had to be considered seriously. Lack of trained welding personnel greatly affected construction in the early stages of the program. Many and various methods of assembly and fitting up of component parts were tried.

The welding engineers had to sell many new ideas as to how parts should be erected in order to properly take care of shrinkages. Some attempted to predict the amount of shrinkage per joint and make proper allowances in layouts; others allowed extra material at certain joints to be cut off when all the welding up to this point was completed. The over-all results were practically the same. Personally, I believe that, with a proper sequence of welding, the extra material left in certain places will take care of this nicely. Predicting shrinkage and making allowances in the length of various assembly units of the hull is very uncertain and may lead to serious consequences if it is not properly engineered by trained personnel.

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Another point of controversy was the arrangement of the butts—whether to have them in line or to stagger them. Although the efficiency of a welded joint was accepted as 100%, there was still some doubt in the minds of many who believed that it is somewhat "safer" to stagger the butts in the shell and let them run into solid plate as an "additional factor of safety." This theory was soon discarded and comparatively large sections of shell were prefabricated with the butts in line.

Welding was the "goat" for all the difficulties encountered in hull construction. If the over-all length of the ship was more than specified, after the hull was completed, welding was responsible because heat "expanded" the steel; if it was shorter than specified, then again it was welding because it had "shrunk" the steel. It was customary to blame welding, because of its newness as a method of construction, for all the irregularities that occurred in the course of construction of the ship.

Materials, equipment and methods, associated with welding, went through their several stages of development and each contributed its share to the progress of the art of welding.

Four years ago, when emergency shipbuilding program started, the steel industry was not prepared to meet the requirements of modern welded construction. There was available practically no structural steel of symmetrical cross sections, so much desired for welding, and designers and builders had to do the best they could to adapt the structural shapes, designed for riveting, into new modern design of welded ship.

Lack of structural shapes of the desired cross section certainly presented a considerable problem to designers and builders to properly satisfy primary requirements and principles of welded construction. In spite of this, it still was possible to utilize available old sections with some modification and save considerable weight.

Some builders adopted the European idea of using serrated beams in various parts of the ship. This type of beam yields itself very nicely to welded construction, in addition to saving weight, in comparison with the conventional type of beam—either angle or T-bar—of the same strength.

Let us hope that when the emergency ends, we shall be able to give our immediate attention to designing new structural shapes that will meet all, or at least most, of the requirements that are necessary to accomplish a perfectly welded structure of the hull.

The quality of mild steel for welding did not improve, and if anything it decreased in uniform quality, which naturally has been due to the tremendous stress placed upon steel manufacturers to produce enormous quantities of steel required by the war industries.

Flame cutting plays an important part in the fabrication and erection of welded ships. Edge preparation for welding by flame cutting contributed greatly to the economy of this operation. There are many types of burning machines which are satisfactorily used in trimming plates to any desired bevel in one operation. A number of machines are being used with multiple burning torches for cutting out shapes of any imaginable design in a single operation. Improvements in Flame Cutting and its application to fabrication have been innumerable.

To speed up the operation of "back-chipping," a gauging burning tool was developed which is successfully used by practically all the yards. It speeds up the preparation of joints for welding and does a very commendable job.

We are all aware that Automatic Welding plays a very important part in any welded construction. There is no doubt as to the quality of a weld produced by the automatic welding process. It is very economical, efficient and fast. Automatic welding is capable of producing the best quality of weld yet known. It has passed the highest requirements for welded joints as to physical and chemical properties of deposited metal.

During the emergency shipbuilding program, welding rod manufacturers contributed much by improving, not only the quality of electrodes, but also the methods of depositing the metal. With the improvements in electrodes, corresponding improvements in the quality of deposited metal resulted. Electrodes are designed for the use in various positions, where they can produce the maximum efficiency in the amount of deposited metal, as well as the highest quality.

Today, there are many selections in welding electrodes for all purposes and almost any condition of welding in any plant or shipyard. There are types of electrodes that can be used with either a.-c. or d.-c. current or both.

Manufacturers of welding rod are striving to produce a universal type of electrode that can be used in any position with either a.-c. or d.-c. current, and produce a high-quality weld with high-impact values and ductility, as specified by E 6010 and E 6011 classes of electrodes. I should not be surprised if this type of electrode is available to the industry before long.

A variety of different edge preparations for butt welding of shell and deck plates were tried out to suit each individual taste. Some yards believed they could produce a better quality and save time using single-V joints; others used a square edge on one plate and single or double bevel on the other, and so on. Many types of butt joints were tried in actual service, and some of them were discarded as unsatisfactory for various reasons. These reasons, naturally, were that the welder was unable to produce a satisfactory joint, or was unable to deposit metal in the groove without leaving excessive porosity in the weld metal; or was unable to fuse the plates together.

Personally, I believe that the double-V joint for butt welding is the best type. It presents itself very readily for balanced welding, consumes less metal, can be produced with less warpage or distortion, and, most of all, truly follows the general and most important rule of balanced heat application and balanced appearance of joint. This type of joint avoids the eccentricity of stress distribution through the joint. Internal stresses are nearly equal on each side of the neutral axis of the plate. We all know that eccentric loading, either external or internal, complicates the joint or the structure, and whenever possible should be avoided.

The argument that this type of joint may delay the erection of steel, or that it takes longer to weld, has no good foundation. Crews necessary to produce this type of joint in proper sequence of balanced welding from one side and the other can be so organized that they will compete with any kind of joint, in time consumed, without any difficulty.

"Twin-arc" welding was tried and, to a certain extent, proved satisfactory. Twin-arc welding is accomplished by two welders welding a butt joint opposite each other, one on each side of the joint. Although the idea behind this procedure is to eliminate back chipping, the main reason is still to achieve balanced welding.

Recently welding rod manufacturers made use of the principles of automatic welding and adopted its technique for hand welding. By controlling the amount of current, speed of welding and the rate of burn-off of welding rod, it is possible to obtain deeper penetration and sounder and stronger fillet welds, than with the conventional method of hand welding.

Some difficulties were encountered with this procedure, but it is reasonable to believe that a solution will be found soon since the basic principle of this technique is sound.

One of the yards proposed, on the basis of actual construction and tests, to substitute "1/2 continuous welds" in place of conventional intermittent welds. This was done in order to conserve welding rod, time and, therefore, cost.

The "1/2 continuous weld" is the procedure whereby one complete rod is deposited on one side of the member, then next one on the other side of the member, and so on. The welds on each side overlap each other about 1 in. In this case, the length of the fillet weld is determined by the size and length of the welding rod used in making fillet welds.

This change in design was presented to The American Bureau of Shipping and the Maritime Commission and I believe it was approved.

The sizes of welds and spacings were necessarily based on rivet sizes and spacing. The amount of weld was specified to transmit the same stress as rivets were doing. At the time, it was the best way of determining the connection, since there was not sufficent time or the trained personnel to design these joints from a purely welding standpoint. Various parts of the ship were left exactly as they were on riveted ships and the rivets that joined these parts were replaced by an equivalent amount of welding. Butt straps were replaced with either butt or lap welds, connecting angles removed and the main parts of the connections fillet welded.

Each yard handled its own problems and made changes to suit its own conditions. The yards worked together and exchanged ideas constantly. The American Bureau of Shipping and the Maritime Commission were very cooperative and helpful in approving the various suggested changes in design or procedures. This certainly helped to increase production, reduce the cost and enable the yards to do a better job with the equipment at their disposal.

It is proper to mention at this point one thing that showed a trend in the right direction—namely: reducing the sizes of the welds. While it did not go as far as we would all like, nevertheless it was a step in the right direction and an attempt to break away from something that was influenced by the riveted type of design.

This step changed the large size intermittent fillet welds, closely spaced, to continuous fillet welds of reduced size. For example: 3/8 x 3 in. fillet weld spaced 6 in. can be changed to 5/16-in. hand, or 1/4-in. automatic continuous fillet weld. This change alone saved many hours of pick-up welding, as required by inspection to correct improperly spaced fillet welds.

The main point of this concession, in my opinion, is that the majority of welds, say in the double bottoms, were brought to the economical and reasonable size of 1/4-in. continuous fillet, which in most cases, is sufficient to provide necessary strength.

The designer should know and appreciate the difference in cost and value in specifying the size of weld for various positions. In some cases it is better to put longer welds of smaller size, than shorter welds of larger size.

We know that intermittent fillet welds produce less shrinkage than continuous welds, but so long as we have to take care of shrinkage, a little more of it can just as well be cared for either by allowing for it or by providing extra material to take care of the shortening resulting from shrinkage.

Other factors such as time, material and, therefore, cost, should be considered. Too much weld is just as bad as, or possibly worse than, not enough. Excessive welding actually weakens a structure instead of adding strength. Oversize welds not only waste welding rod, but they add unnecessary heat input and wasted man power.

Table 1 shows comparative values as to the pounds of welding rod and time required to make 100 ft. of weld of three common sizes, in various positions.

From the table, we can see that the 5/16-in. fillet weld requires about 56% more metal than 1/4 in., and 3/8 in. requires approximately 43% more than 5/16 in. The time consumed in depositing the various sizes of fillets in down-hand positions does not vary appreciably for the reason that large size electrodes are used to deposit the required fillet in one pass.

When we compare the vertical and overhead positions, in which positions most of the welding has to be performed on a ship, the total time consumed in making the different sizes of fillets varies considerably. You will note that arc-time hours, that is, the actual time required to deposit a certain size of fillet weld in vertical and overhead position, is practically the same. The efficiency factor is different, however, because fatigue is greater in the overhead position than in the vertical.

Now, suppose that for some reason a 3/8-in. fillet weld was specified in a certain place where 1/4-in. fillet weld would answer the purpose. It will take 32.50 hr. to deposit 100 ft. of 3/8-in. fillet weld in the overhead posi-

Table 1—Comparison of Maximum Welding Time Required to Weld 100 Lineal Feet of Various Sizes of Fillet Welds

SIZE OF FILLET	DOWNHAND					VERTICAL				OVERHEAD			
	CU. IN OF WELD PER 100 FT	AWS ELECTRODE SIZE	ARC TIME HRS MAX	NORMAL PROFFIC %	TOTAL TIME HRS	AWS ELECTRODE SIZE	ARC TIME HRS MAX	NORMAL PROFFIC %	TOTAL TIME HRS	AWS ELECTRODE SIZE	ARC TIME HRS MAX	NORMAL PROFFIC %	TOTAL TIME HRS
1/4"	41.3	E6012 1/4"	1.892	50	3.78	E6010 5/32" 3/16"	5.67 4.36	40	14.15 10.80	E6010 5/32" 3/16"	5.67 4.36	30	18.85 14.52
5/16"	64.4	E6012 1/4" 5/16"	2.96 2.01	50 50	5.92 4.02	E6010 3/16"	6.17	40	15.40	E6010 3/16"	6.17	30	20.58
3/8"	92.4	E6012 5/16"	2.51	50	5.02	E6010 3/16"	9.76	40	24.38	E6010 3/16"	9.76	30	32.50

NOTE: NORMAL ARC PROFFICIENCY TAKES INTO ACCOUNT FATIGUE FACTOR FOR VARIOUS WELDING POSTIONS

tion, and only 14.52 hr. for the 1/4-in. fillet weld. In the vertical position, it will take 24.38 hr. for the 3/8-in. fillet weld, and only 10.8 for the 1/4-in. fillet weld. In other words, it takes more than twice the time to deposit a 3/8-in. fillet weld than it would take for the 1/4-in. fillet weld.

So the oversized weld specified on a drawing by a draftsman or engineer without good reason or study, costs a considerable amount in wasted man-hours and material, not counting the actual harm done to the structure by the oversized weld.

Consider the C-type cargo ships. True, we are applying to it the general principles of welding design. But it was, and still is, based on the riveted design. There was not sufficient time or actual data on the behavior of welded ships of this size on which to base definite conclusions or make radical changes from the riveted design to the welded design. Moreover, we had to be cautious in deviating from something that had been proved and going all out for a new type or construction that had not been tried out sufficiently to clear up all the points. So we had to prove each point as we went along and proceed very slowly with changes.

The efficiency of the welded butt joint is accepted as 100%, which means the welded joint is just as strong as the parent metal it joins. Structurally, it produces a homogeneous, continuous member which transmits stresses through the parent plate and joint alike without interruption. Of course, this must be true only in cases where the weld is made properly, with full penetration and even, symmetrical crown.

The early welded designs of hulls specified inserts and doubler plates with square corners (inherited from riveted design), but were soon revised and the radius corners were provided. It was not long before every weld-minded man became "notch" conscious, and seriously appreciated that it is next to impossible to cut out a square hole without leaving a notch in the corners.

The Hull Designer, among many other things, is paying particular attention to the shape of the hull, so that it will present the least possible resistance to the outside forces of wind and sea. In other words, he streamlines the outside shape of the ship just like the designers of automobiles, locomotives, etc. We are all aware of these external forces and try in every way to avoid them by streamlining the exterior of the structures.

We should have the same idea in mind when we design connections between the main members of the structure. The connections should be simple and provide a gradual change in sections, so as to present the least resistance to the flow of stresses. Unbalanced connections introduce secondary stresses in the structural members, and in addition to thermal stresses created by welding, may result in failures. By rearrangement of parts comprising the connections the stresses may be directed through easy channels and flow in a normal manner.

This rule applies not only to a member or a connection, but also to a joint itself. Symmetry and balance should be given due consideration, when selecting the type of weld or groove for a joint,

Insert plates in the deck or shell plating should be gradually scarfed to the thickness of the thinnest plate, and the weld should be no greater than that required for the thinnest plate. After all, the heavy insert plates are put in only to compensate for the material cut out from the original plate, and to reinforce the openings that are necessary for king posts, masts, sea chests, etc.

Metallurgically, the joint is just as important. As we brought out before, the weld metal must be as close as possible to the physical and chemical characteristics of the parent metal. It must have the same qualities of strength and elasticity. There would be no object, for example, in inserting a high-tensile strength link in a chain, because the chain would be bound to break in its weakest link. In the chain of parent metal and weld metal deposited in a joint, we should have metallurgical uniformity, just as we should have structural streamlining that will tend to avoid concentration of stresses and provide a uniform path, or gradually changed path for stresses to travel.

Now let us examine the inside structure of a ship. The shelter deck of a ship and the bottom are the most important parts, from a structural point of view. Roughly, a ship's hull may be compared to the beam or girder that carries a complicated load. It is true that a ship's hull in service is subjected to such complicated forces that it is hardly possible to trace these forces through the hull structure and be able to predict the actual flow of stresses. But we still can investigate it by applying the simple rules of stress analysis. We all know that stress in bending is at its maximum in the outer fibers of a beam. In the hull structure we can compare the top deck and the bottom of the ship to the two outer flanges of a beam, where the stress is maximum, with the neutral axis of the section passing somewhere between the top deck and the bottom shell.

When a ship is at sea, the hull is constantly subjected to bending, and stresses in the top deck and in the bottom of the ship alternately change from the tension to compression.

The bottom of the hull presents fairly uniform construction, with its tank top, longitudinal girders and floors. The sections of the bottom change gradually and uniformly by easy, smooth, streamlined increments. There are no abrupt changes in sections and even the connections are simple and balanced. There are no openings of any magnitude to cause an uneven, interrupted flow of stresses through the longitudinal members of this part of the ship. The tank top (or inner bottom) is spaced relatively close to the bottom shell and may be considered very effective in helping the outer bottom plating to act as the outer flange of the beam, and absorb a good part of the maximum stresses that are concentrated there.

We look for and pay particular attention to any unfairness in the bottom plating and suspect that excessive kinks in the plating between the transverse frames may cause the collapse of the outer flange of the hull girder, due to compressive stresses. The top deck (shelter or strength deck—whichever you may prefer to name it) must perform the same duty as the bottom of the hull, namely, act as the outer flange of a beam. But as it stands now, with the multitude of insert plates of various thicknesses, and big square openings, with their own complement of reinforcement, it presents quite a complicated highway for the stresses to travel through.

The midship area of the hull is subjected to the maximum bending stresses and should be so designed as to present the least possible resistance to the flow of internal stresses. Instead, we find that, in this most critical area, we have a big, square opening that abruptly cuts out more than a third of the effective area of metal. The opening is usually made with sharp, square corners (see Fig. 1 (*A*)) and the girders, which are part of the member designed to resist the "maximum moment," project through the deck with an abrupt change in sections to form the hatch coaming, meeting the square corners of the opening with square corners on the girders. This arrangement puts together two of the weakest points in the same place, because stresses in the deck and girder, distributed throughout their full width and depth, suddenly have to crowd themselves into an area which is abruptly reduced by at least one-third.

Changes in deck plate thicknesses, due to insert

plates, throughout this area present the same condition.

Through the experience gained thus far, I believe that in the future the top deck will be designed and constructed somewhat differently than it is now. Some improvement in hatch corners has already been made by providing a radius in the corner of the insert plate, although it leaves the hatch of the same square cross section. By increasing the thickness of deck plating throughout the midship area, and providing oval (see Fig. 1 (*B*)) or some other shape of hatch opening, with long radius corners, so that the stresses may easily and without obstruction flow through reduced areas of the deck metal without concentration—there will be no reason for having corner insert plates. As it is now, the only reason for the corner insert plates is to reduce the intensity of concentrated stresses by providing more area of metal.

If means are provided to give a free, unobstructed passage for stresses, there would be no reason for these corner insert plates.

The arrangement of the deck plating will be much simpler by using longer and wider plates, which will reduce the number of seams. Reinforcement of the openings for king posts, masts, etc., will be achieved by some other means than insert plates, in order to keep the cross section of deck plating as uniform as possible, and in order to simplify the welding procedure, thereby reducing warpages, shrinkages and stresses associated with welding.

Supporting members of the decks, such as hatch end beams and longitudinal girders, certainly will be of different shape than the present L-shape. The L-shape section in itself is unbalanced from a structural standpoint and presents a difficult problem for designing efficient balanced connection.

In some welded ships, the side shell plating extends above the top deck approximately 5 to 7 in. to form a gunwale. We all appreciate the importance of having the edge of the gunwale smooth, without sharp indentations; we do not want any deck fittings or other parts to be welded to it, because any notch in it or fitting welded to it, will abruptly change the section of the gunwale and concentrate the stresses at this point. The uppermost edge of the shell plating that extends above the deck is part of the top flange of the girder and is at the outermost fibers of this flange, where the stresses are the maximum. The area of steel in just that portion of top flange of the girder (gunwale) is very small and therefore greatly overstressed. To what extent this section of the hull girder is overstressed, I do not know but the fact remains that conditions of this nature exist.

The gunwale is inherited from the riveted design, in which it had the purpose of forming the top connection between deck and shell. In that type of design, it probably had some structural value, since there was, in addition to the shell section extending above the deck, also bounding angles on the top and bottom of the deck, concentrating a considerable area of metal that served to distribute stresses in this section in a manner not so severe as it is in welded construction. In its present form the gunwale is just as detrimental to the hull girder as an excessive buckle in the bottom shell, or continuously welded bilge keel, and probably more so.

It is reasonable to believe that in the future the gunwale will be eliminated entirely, at least through the midship area, unless there is a very good reason for retaining it in its present form. If there is, I am sure there are ways of providing for its functions in such a way that the gunwale will not be an integral part of the main structure, and will have no influence on stress distribution in the hull structure itself.

Sea chests, and other outlets, cutting through the shell plating are reinforced again with insert plates of greater thickness than the shell plate itself. In the majority of cases, the size of insert plate, to compensate for the opening, was determined without any regard to the location of seams and butts in the shell, which unduly put another additional burden on the prosecution of welding.

Recent designs for certain types of ships at least partially realized the problems of welding and made this insert plate as part of the complete shell strake.

Openings that may come in any strength section of the

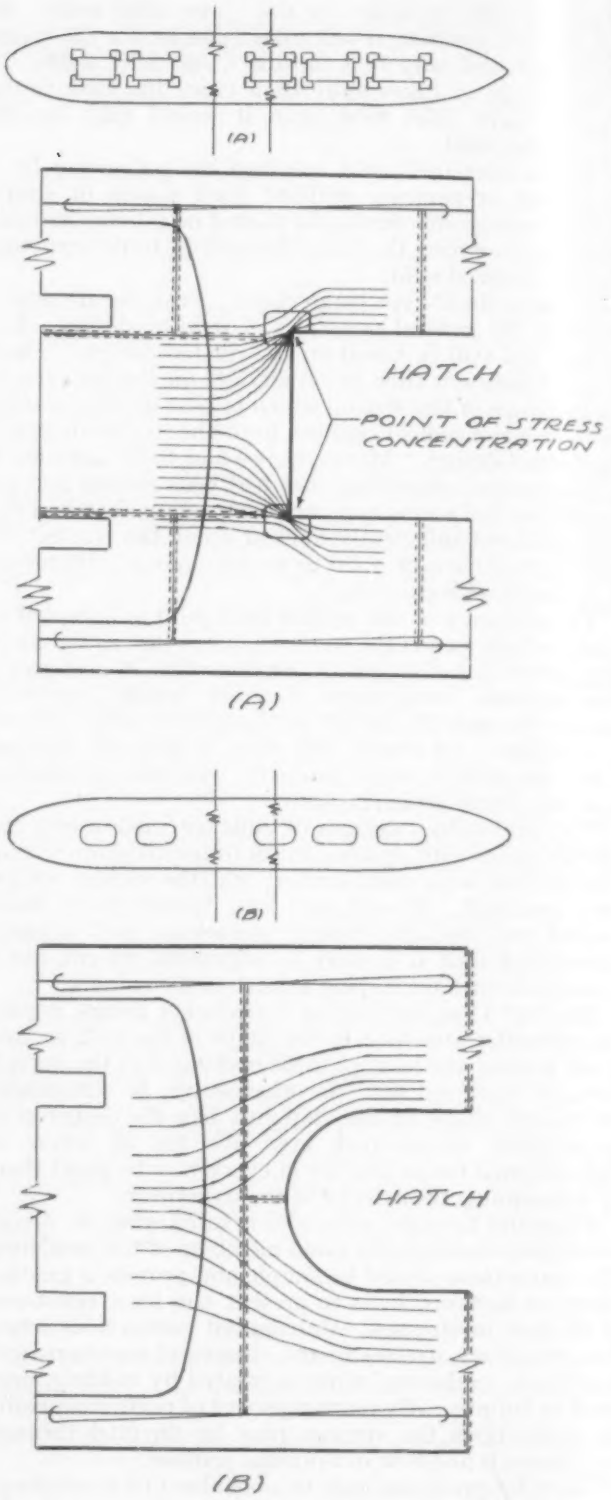

Fig. 1

structure are an evil necessity and should be cared for in such a way that they will not aggravate the condition forced by necessity.

As I stated above, in the case of the shelter deck, we must provide for easy streamlined avenues for the passage of stresses, so in this case I believe a different shaped opening should be provided to get away from sharp, square corners which are a meeting place for stresses.

I do not believe there will be any objection to have these openings and making boxes for sea chests in the oval or round form, which will give easy passage for stresses around the opening, and not complicate the structure either from the assembly or welding point of view.

The emergency shipbuilding program which has crowded many years of development of welded ships into the short period of 4 yr., gave to the welding fraternity an opportunity to apply its knowledge and to show its ability to produce what they believed to be the best in modern construction.

Enough publicity has been given recently on various failures of welded ships, presumably due to locked-up stresses in the structure of the hull, due to welding. What part thermal stresses, due to welding, play in such failures is not generally known now, but a number of scientists are at present studying the problem, and we can be fairly sure that the findings are not too alarming. If they were, welding in shipbuilding would be curtailed to a great extent right now.

The objections that welding produces a rigid structure is not conclusive enough. The structure, no matter how it is joined, can be designed to any degree of rigidity by properly rearranging members, and this is the problem for Naval Architects or Structural Engineers, who are capable of solving it.

I believe that we all agree that a 100%, or nearly so, welded hull presents practically a monolithic structure. Then let's deal with it as one.

Let us design the connections between the various members of the ship so that they will be able to function properly and each deliver its share of stress. Let us select proper joints that will be not only structurally, but also metallurgically balanced, and let us make structural sections that will adapt themselves to the accomplishment of this goal.

During this period of the emergency shipbuilding program we have obtained a great wealth of knowledge on the behavior of welded ships. In the future, when industry will return to its normal and we have had the chance to apply our additional knowledge to the various phases of ship design and construction, we will be ready to produce the truly 100% welded ship.

Low-Reactance Cables for Portable Resistance Welders*

By Myron Zucker†

SPOT WELDING is used primarily because it speeds production. That is why "gun" welders have their place, and, carrying the sequence one step further, that is why low-reactance cables are becoming the accepted means of carrying the electricity between transformer and gun.

The speeding up of production on the home front by low-reactance cables is similar to the improvement in shooting that the bazooka has made on the battle front. The soldier with a standard "shooting iron" and the welder with a gun fed by ordinary cables, both wish their guns wouldn't kick out of position when fired. In the Army, the bazooka meets this need, and gives the gunner a heavier wallop: in the factory, the Kickless Cable does the same—it stops the kick, and gives the welder a stronger, faster punch. That is the main reason for the increasing acceptance of the equipment in both fields of activity.

Of equal importance in high-speed production, the quiet operation of low-reactance cable means greatly increased life. There is a marked contrast to the action of ordinary cables that tear themselves to pieces by abrasion and fatigue. Every welding supervisor has had his hair-tearing moments when he finds that the needles worn from single conductor cables have plugged the water lines. This does not happen in low-reactance cable, for the "kick" is absent. This stability produces direct economic advantages for the user: Kickless Cables' reliability and long life actually decrease cable costs.

Because costs are so important in the factory, we will mention here the other economic advantage of this type of cable besides increased production rate and longer cable life. That is, the reduced size of electric supply equipment—transformers, feeders, contactors—required to do a given welding job.

Strangely enough, these mechanical effects and the resulting economic benefits, are all by-products of the main idea behind the low-reactance cable. Just as electric welding is a by-product of Elihu Thomson's efforts to produce electric light, just as atomic-hydrogen welding is derived from Dr. Hull's study of hydrogen disintegration for altogether theoretical purposes, so these *mechanical* and *economic* values of the interleaved welding cable grew out of the development of a design to improve the *electrical* effectiveness of gun-welding equipment.

It is therefore appropriate that we pay more attention to the electrical benefits, which are important in themselves. Low-reactance cable gives higher welding currents with better power factor and lower demands on the power supply system. These results are derived from the same basic point that produces all the other improvements: the practical elimination of reactance in Kickless Cable. If we understand the direct mechanical and

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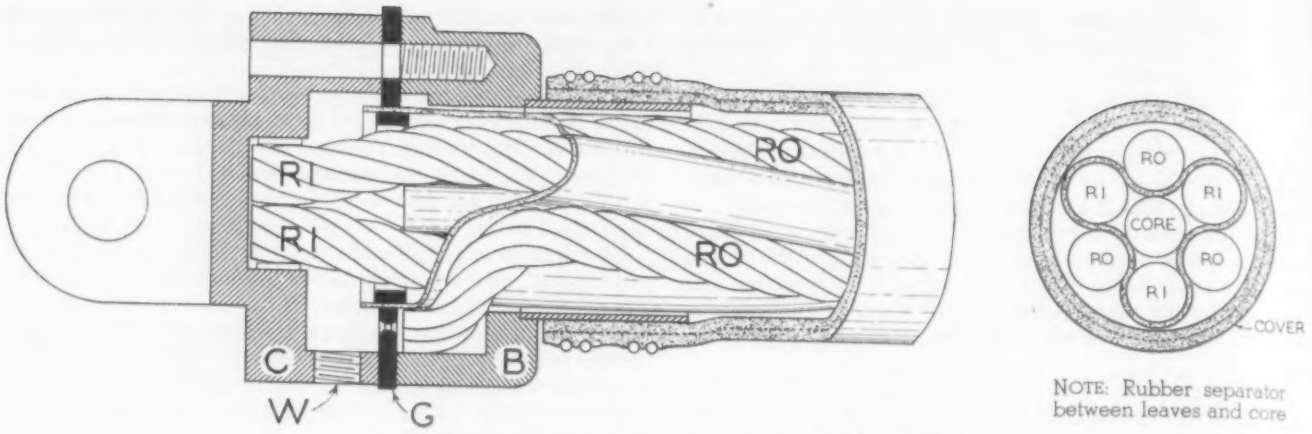

NOTE: Rubber separator between leaves and core

Fig. 1—Interleaved Low-Reactance Welding Cable

electrical results of low reactance, the benefits previously outlined become apparent. Therefore, we will consider four direct technical questions:

1. How does the interleaved construction eliminate cable kick?
2. Why is less copper required in low-reactance cable than in ordinary ones?
3. Why can the electrical power supply equipment be smaller with low-reactance cable?
4. (*a*) What is the meaning of power factor to the welder user?
   (*b*) How does the user benefit from low-reactance cable's improvement in power factor?

Cable Construction

To answer the first question, we must describe the cable construction. The interleaved form* (Fig. 1) not only has lower reactance but is favored by greater mechanical adaptability of terminals, inherent economy of manufacture and effectiveness of water cooling of the conductors. This interleafed construction has proved itself in eight years' industrial experience.

The Kickless Cable in its present form consists essentially of six ropes, laid helically around an inert core. Three ropes (*RI*) are inside a rubber separator, and three others (*RO*) are outside. The three outer ones (*RO*) terminate in recesses in the base (*B*) of the two-part terminal, whereas the other three (*RI*) enter the terminal cap (*C*). These two parts of the terminal are separated by an insulating gasket (*G*) of special design, and each part has provision for external electrical connections.

The water circuit starts at the inlet (*W*). (This is normally at the gun end of the cable, so the operator has a cool cable to handle. Also, since the gun is usually below the transformer, connecting the water inlet at the gun end of the cable permits air bubbles to be carried to the top and out of the cable.) Water fills cap (*C*), from which a stream is admitted to each rope through openings in the gasket. These openings are so designed and proportioned that inner and outer wires are held at the same temperature. Since the water runs right down the wire, the copper is at practically the same temperature as the water. This method eliminates hot spots in the ropes, and gives long cable life.

Why No Kick

Now let us see how this arrangement of wires eliminates kick, remembering that kick is simply the electric motor action of currents flowing in opposite directions. In ordinary cables, the forces amount to hundreds of pounds with the currents and cable lengths commonly used. The closer the cables are bound, the higher the forces pulling them apart (Fig. 2). This is shown by the disintegration of the tapes with which cables are frequently tied, and by the needling of conductor previously referred to. (Incidentally, this action is often aggravated by the pulling and wrenching of bound single conductors where one is connected to a moving terminal on the gun.) It is common knowledge that after a short time, so many wires break in single-conductor cables that the increase in resistance cuts down the welding current, requiring constant adjustment of timing or transformer taps to secure satisfactory welds.

In contrast, Kickless Cable has practically no net force acting on the ropes. There are three reasons for this:

a. Dividing current into three parallel paths reduces the forces between all conductors to one-ninth.
b. The hexagonal pattern of wires makes the repelling forces between conductors of opposite electrical signs (that is, *RO* to *RI*), act at angles and partly oppose each other (Fig. 2)—and further neutralizes them by the attracting force of conductors of the same sign (*RO* to *RO*).
c. The spiraling of ropes makes each rope act as structural member that resists motion by means of its tensile strength.

The theory is borne out by the fact that thousands of amperes may be passed through a Kickless Cable from which the outer cover has been removed—and the cable stays motionless. The kick has practically disappeared because of low, balanced forces and the self-supporting structure.

That is the answer to Question 1. Before going to Question 2, we will review a few points concerning elec-

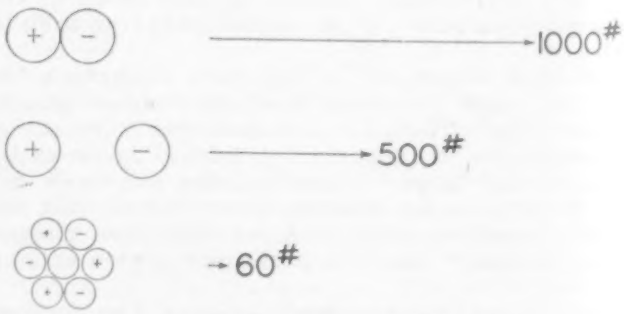

Fig. 2—Forces Between Cables

* Mackworth, G. Rees, Inventor, Pat. No. 2,247,133.

trical characteristics. Although these ideas are known to be true, they are not always taken into account when welding equipment is specified.

Basis for Choice of Cable Size

First, the size of electrical equipment for welders must be based upon *the current required to make a weld, not* upon the kilovolt-amperes that have been required by past practice. As stated forcibly on page 285 of the 1942 *Welding Handbook:*

"There is one and only one basic index to the welding ability of a resistance welding machine in terms of the electrical ability to perform a given welding job. That index is *secondary current.* We can definitely state that the maximum secondary current which a welding machine will deliver at the weld is the true measure of the welding ability of the machine in so far as the electrical characteristics are concerned."

This current depends, of course, upon the voltage that is available and upon the electrical resistance R and reactance X of the circuit to which the voltage is applied.

In relation to Question 2, the significance of the *Welding Handbook's* statement, therefore, is that with a welding transformer of given voltage the R and X of the welding circuit must be kept low enough so that the available voltage produces the required current.

This leads to the second point: that is, for the purpose of selecting electrical units for portable gun welders, the *secondary welding cable is the load.* Not the weld, but the cable is the load. All that the weld does is to act as a sort of commander that tells us how much electrical load must be supplied to the cable in order to do the job. For example, when a weld is being made the metal may absorb 1 v., the gun and welding transformer may take 2, but the flexible cable may require 10 (see Fig. 3).

This means that our previous statements about keeping R and X low, apply primarily to the welding cable. That is, we must make sure that the available voltage is sufficient to send the required current through both resistance and reactance of the *cable*—with some margin for gun, transformer and weld.* If the reactance is high, the situation can be helped by making the resistance low—which may be done by using larger conductors.

This is the basis for answering Question 2: Why is less copper required in a Kickless Cable than in an ordinary one? In the low-reactance cable, the voltage required to overcome reactance is minimized, leaving most of the transformer's voltage free to overcome the resistance. Ordinary cable, on the contrary, has high reactance. This must be compensated by keeping the resistance low—which calls for larger, heavier cables.

We can give this general answer more meaning by taking a specific case: What size ordinary cables will be required to replace a 10-ft. heavy-duty (450 mcm.) Kickless Cable welding 18-gage mild steel with 10,000 amp.? (We are now considering only the electrical ability of the equipment to supply enough current to make a good weld. This is the limiting factor on jobs having low duty cycles. On high duty cycle work, the *capacity* to supply the current over a long time without overheating may determine the size of equipment. That subject will be covered at another time.)

The answer to this problem surprises any one who has not seen the two types of cable in action; for each ordinary cable would have to be over 1,500,000 circular mils! In other words, to do a given welding job with a certain transformer and gun, the welder has his choice of handling two 1500-mcm. cables each 1.6 in. outside diameter, or one 450-mcm Kickless Cable, 2.25 in. outside diameter.

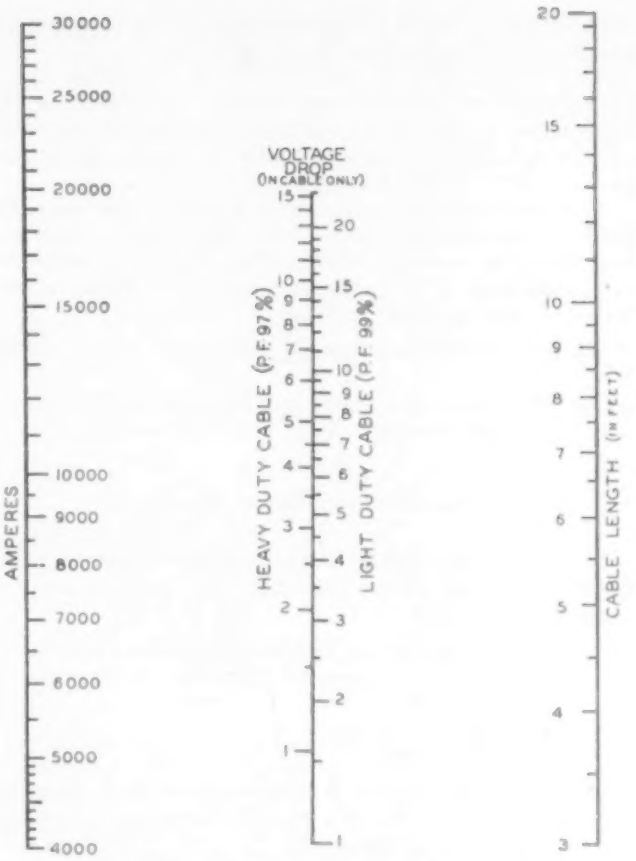

Fig. 3—Voltage Drop Data for Low-Reactance Cable

To find the voltage required to send a given current through a certain length of cable, place a straight-edge between the known values of current and length, and read the voltage where the straight-edge intersects the middle scale.

Note: These data apply only to the interleaved cable having six conductors, hexagonally around a core, 1/16 in. spacing between ropes; light duty size made of six 89 mcm. ropes, heavy duty of six 150 mcm. ropes; operation at 70° F., water inlet and 160° F., water outlet.

Lower Electrical Power Demand

Question 2, just answered, represents the welder's viewpoint. Number 3—why can the electrical power supply equipment be smaller with low-reactance—is of more interest to the plant engineer, who is first concerned with the size of the welding transformer. Working from the fundamentals previously outlined, he compares the voltage requirements and the secondary kilovolt-amperes for Kickless Cable (see Fig. 3) and for two ordinary ones of similar size and cost, as follows:

	Voltage Across Cable	Demand on Transformer Secondary (Including Weld Load)
450-mcm. Kickless Cable	5.3	72 kva.
Ordinary cables	11.0	142 kva.

The lower demand when Kickless Cable is used, means a smaller welding transformer can be used. In addition, the lower demand reduces the size of contactor and low-voltage bus. It may also reduce the size of substation

* See "Electrical Characteristics of Resistance Welding Equipment," Cooper, *The Welding Journal RWMA Bulletin* N. 7, February 1942.

power lines and even the generator, if this type of load is a sufficiently large part of the total.

This comparison, is the answer to Question 3. It shows that by selecting gun-welding equipment of the proper size to supply a designated current to the weld, appreciable savings may be made in supply equipment as determined by the demand.

That saving in demand is only a part of the story, for the load that must be spent on low-reactance cable is not only lower in amount—but, as we shall soon see, it is more desirable in character because it has higher power factor. This leads to Question 4:

(*a*) What is the meaning of power factor to the welder user?

(*b*) How does the user benefit from low-reactance cable's improvement in power factor?

Importance of Power Factor

Let us answer the second half of that question first. Improved power factor benefits the user because it means:

1. Less voltage-flicker interference with other equipment and consequent *reduction* in number of *spoiled welds*.
2. Less expensive feeders.
3. Lower power bills.

Although these affect the plant engineer more than the welder, they are so much a part of the story that even nonelectrical men are interested.

We will approach Question 4 (*a*)—the meaning of "power factor"—by supposing you are in the Army for a few minutes—in a Duck landing on the soggiest beachhead you ever saw. Stuck? Certainly, but you have a cable and winch for just such situations. All you need to do is hook onto a tree, throw the winch in gear and pull yourself out. You see two trees (Fig. 4), one straight ahead, and a somewhat bigger one 45° off to the left. Which tree will you choose?

The tree on the left is strong. It is sufficiently far ahead so that if you tied up to it, part of the pull your winch can exert will draw you forward, where you want to go. Since the Duck is in a groove, it cannot move off sideways. Still, you know that tree isn't the right one to choose. Although you might get out this way, it means extra strain on the winch, pulling the wheels sideways against the rut. An even more serious objection is that it puts added strain on the cable—perhaps enough to break it. You have a flash of technical verbiage: you say that the useful power, represented by pull P (Fig. 4) is only a small fraction of the total power T. This setup would not be very effective because the *power factor* P/T is low.

The better way is to hook on straight ahead, where the power factor is high. Direct action, minimum strain on

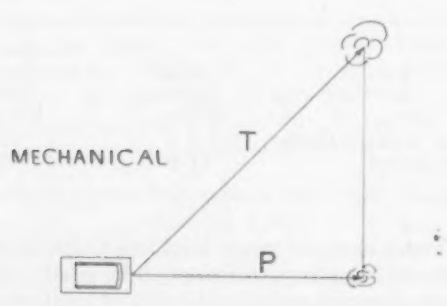

Fig. 4—Added Force Due to Pulling Out of Line

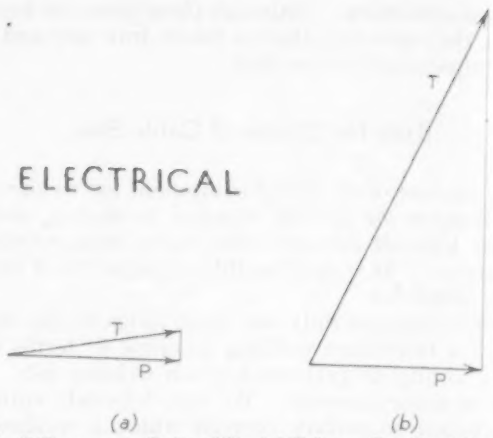

Fig. 5—Difference in Ratio of Useful Voltage P to Total Voltage T
(*a*) Shows relation in low-reactance cable: P is nearly equal to T.
(*b*) Shows ordinary cable, with P only a fraction of T. The latter means high electrical demands and low power factor.

the cable and winch. It gets you out with much less fuss and feathers, and less chance of overloading the cable.

So it is when there is an electrical job to be done, although we use a different set of words. In welding, the purpose of the electrical system is to deliver power to a heat-absorbing element, which is called a resistive load. Any work done there is useful—like pulling straight ahead on the Duck. But in most circuits you can't work so directly: it is necessary to supply electrical force, or voltage, to overcome not only the resistance of the path, but a "sideways" effect called the reactance of the circuit.

Low Reactance-Good Power Factor

Reactance is important enough to warrant reviewing its causes so we can better understand its relation to the gun-welding circuit. The fundamental point is that when an alternating current flows down a stranded wire, the current in each strand acts, through the magnetic field it sets up, to try to stop the current flowing in the other strands. (Each of these is also affected in the opposite direction by the current in the return conductor, but since the forces are smaller because the current is at a greater distance, we will neglect this for the moment. Later, we will see its importance.)

We can say, then, that there is a *reaction* that induces a voltage opposing all attempts at current flow. It does not absorb power, but it does require that to maintain a given current, a "sideways" voltage—called the reactive voltage—be applied to the conductors in addition to that used to overcome their resistance. This corresponds to the added pull that the Duck must exert in the case of the out-of-line tree.

In fact, electrical quantities can be drawn geometrically just like Fig. 4. The force or voltage that gets you where you want to go (i.e., the *resistive* voltage required to overcome the resistance of the circuit) can be shown as P in Fig. 5; the reactive voltage that gets you nowhere but still must be applied, is combined with P to produce the total force T. In this case also, power factor is P/T.

That is all there is to the term that mystifies so many people when they hear about "electrical power factor." It is simply the ratio of useful force to total force.

Figure 5 illustrates the contrast between the high power factor obtained with low-reactance cable and the low power factor resulting from ordinary cables. In both cases, the resistive voltages are about equal if there

is the same amount of copper. But there is a radical difference in the reactive voltages—because the reactances are so different.

Why Interleaving Lowers Reactance

The reduction of reactance in the interleaved cable is based on the principle that the voltage induced in a given strand is higher when the current is closer to it. Therefore, by properly distributing the current in various conductors, the opposing voltage induced in a "going" strand by other currents in the same direction, can be materially reduced. More vital, the assisting voltages created by the returning current, mentioned parenthetically before, can be greatly increased by placing these currents close to the "going" strand. This makes a remarkable improvement over ordinary cables.

In ordinary cables, the opposing voltage is high because the "going" current is concentrated in one wire and hence produces large countervoltages. There is but little amelioration of this effect by the opposing current, because it is all in one wire at a relatively great distance. In contrast, the countervoltage in interleaved cable is considerably reduced by dividing the current into parallel paths so that the average current is farther away from a given strand. Further reduction in reactance is obtained by placing conductors carrying "helpful" currents, close to the other wires.

Thus, in Kickless Cable the reactive voltages are first reduced and then cancelled to a considerable extent. This results in a net opposing voltage, or reactance, of about one-tenth that found in ordinary cable.

This means, in terms of Fig. 5, that the sideways voltage is much lower with Kickless Cable. Therefore the power factor is higher.

It has already been shown that higher voltages required for a given current, mean higher demands. It may also be stated that when these demands are at poor power factor, they cause greater voltage dips in the supply lines.

These are the two facts that make power factor important to the welder. Poor power factor, companion of ordinary cable, means high demands, plus spoiled welds and flickering lamps due to unnecessarily high voltage dips in the supply circuit. Finally, the user will be penalized, directly or indirectly, by higher power bills.

On the other hand, the user benefits from the improved power factor associated with low-reactance cable because his equipment draws less primary current, and causes less voltage drop in the feeders and transformers. In many cases it also decreases power bills because the generating, transmitting and distributing system can all be smaller and therefore the power company can charge less for its services.

That is the answer to Question 4.

Correct Electric Circuit Essential for Welding

In view of these electrical considerations, we can appreciate how Kickless Cable makes possible some of the more difficult gun-welding jobs being done today on heavy steels or large pieces, and on those metals that demand quick, heavy impulses for successful welding.

One example of a problem solved by these cables is the welding of reinforcing channels 10 ft. long to steel sheets (Fig. 6). The job was first set up with two complete gun welders, one for each side of the channel. Ordinary 400-mcm. cable carried the current from floor-mounted transformers, to guns over the piece. Two copper backing plates extended the length of the portion to be welded. They acted as bus bars to which the second side of the transformer output coils were connected.

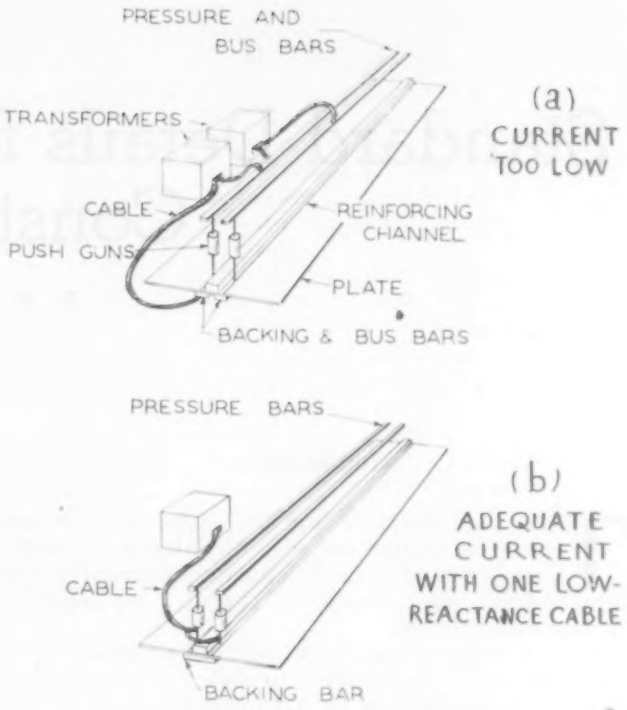

Fig. 6—Low Reactance Cable Makes Possible the Welding of Reinforcing Bar to a Sheet. In (*a*), the Original Set-Up, Current Was Too Low for Weld, Because of the Reactance of the Circuit from Transformer Through a Single Conductor to the Backing Bar, Push Gun, Upper Bus Bar, and Then Through Other Single Cable Back to Transformer. In (*b*), the Circuit Is Through the Low-Reactance Cable, Down One Gun to the Backing Bar and Back Up the Other Gun. Current Is Multiplied Several Times, and Welds Are Made Routinely. Incidentally, Transformer Bank Is Halved

The secondary current, therefore, traveled over a large loop in which lay a sizable piece of steel. With the resulting high reactance, so much voltage was absorbed that the remaining voltage from the transformer was insufficient to produce the "forward" effect that would heat the welding spot. The $^1/_8$-in. reinforcer would not weld to the No. 12 sheet.

Realizing that reactance was the trouble, the supervisor installed as much Kickless Cable as possible to replace ordinary cable. This increased the current to where the welds could be made. The final step, however, really solved the electrical problem: the supervisor connected the two backing bus bars together to act as a backer for series welding, brought the current all the way from the transformer to the two guns by a single Kickless Cable, and now welds in a routine manner with higher currents and half the transformers.

This illustrates how low-reactance cable, used in series welding, brings a difficult job down to the realm of standard practice. Although this is an unusual case, it invites attention to the point that the most effective welder from the viewpoint of electrical power supply, is one that has a minimum of loops. In other words, it is best, electrically, to supplement low-reactance cable with low-reactance load—by using a series welding head wherever the throat of a simple fixture becomes overly large. It is true that current shunting within the metal may dissipate this advantage, and that the mechanical setup required for series welds may be undesirable. But when these factors are favorable, great improvement may be obtained in welds, and savings made in the electric supply end by use of series welding, with low-reactance cables. This applies to pedestal type welders even more than portable units.

Standard Details for Welded Building Construction*

By H. W. Lawson†

Introduction

THE part which welding has played in war production has created considerable interest in welding which should result in a greater demand for structural welding when conditions permit a resumption in civilian construction.

If the welding industry is to take full advantage of this demand it will be necessary to provide a much greater degree of standardization in welded details. The Structural Engineer has been accustomed to design his riveted structure and leave to the Fabricator the design of the details, at least for conventional beam-and-column framing. While he has usually approved the details, most of them were long accepted standards and only an occasional connection required any original design. Such is not true of welded details. Unless the designer indicates on his drawings the types of details he wants, he may get any of a large variety of types, depending on the experience and preferences of the Fabricator. This leads the Engineer to believe the process has not yet developed sufficiently for the Engineer to utilize it unless he has the time to acquire a working knowledge of the art.

Should he desire to inform himself on structural welded details he will find a large amount of information available in various books and pamphlets, codes, specifications and handbooks. However, the wealth of information but adds to the confusion of one who hopes to "pick it up in a few easy lessons" since each specialist has his own pet ideas and what is recommended by one will be condemned by another, and there is no authoritative source such as the AMERICAN WELDING SOCIETY *Handbook*, The American Institute of Steel Construction *Handbook* or even a steel company shape book, to say that "this is the most acceptable detail for such a purpose," or even to go so far as to say "this is the accepted design assumption or method" for a specific problem.

There are still too many differences of opinion among the leading specialists, about minor considerations which it would be to the Industry's advantage to integrate into definite recommendations with authoritative backing. If this could be carried to the point where standard design assumptions, and standard details for conventional framing, could be established, it would also result in lower engineering, drawing room and fabricating costs.

The purposes of this paper are:

1. To show that there is now an adequate basis in research, particularly in that conducted over the last fifteen years at Lehigh University, to justify an agreement on the principles of design for beams and their welded connections;
2. To offer for the case of greatest first interest, viz., the typical case of simply supported beams, a set of welded details which with their capacities, are ready for handbook publication and general professional acceptance.

Some of the High Spots of the Research

Only a very condensed summary of the research alluded to can be included in this paper, and those interested in a more detailed study of this subject are referred to the bibliography at the end of the paper.

An investigation of Web Buckling in Steel Beams[1] established web crippling as a more critical factor than buckling in the design of beams supported on seats, confirming the formula $a = (R/24t) - k$, since adopted into the American Institute of Steel Construction Specifications. While not a welding research, the principles involved are used in the design of seats, both flexible and stiffened. See Fig. 1.

An investigation of the Behavior of Fillet Welds when Subject to Bending Stresses[2] developed interesting facts about welds subjected to shear and moment. The conclusion most pertinent to this discussion is that ordinary design formulas will give average stress conditions in the weld up to the yield point. There are certain other conclusions as to stress distribution, methods for computing combined stresses, etc., which are worth reviewing by anyone desiring to become well informed on the subject. Further discussion on this subject is also presented in a later report on Stress Distribution in Welds Subject to Bending.[3]

The welded seat angle was covered in an investigation of Welded Seat Angle Connections[5] and a Photoelastic Study of Bending in Welded Seat Angle Connections.[4] This subject will be discussed more fully later.

Stiffened seats or brackets were covered in a report on Structural Welded Brackets[6] and will also be discussed later.

Top angles suitable for use with seats or brackets, and side framing angles are covered in a report on Flexible Welded Angle Connections.[7] This investigation established that flexibility in such connections may be obtained without damage to the welds, even when the angle deformation extended into the plastic range.

Miscellaneous Welded Building Connections[8] were investigated as a sort of fishing expedition to determine if some of the less common details possessed virtues which could be developed by further research. One of the features of this report was the introduction of moment-rotation curves for the various connections, which makes it possible to readily determine the suitability of a detail for any particular service or type of construction. (Fig. 26.) The general conclusion of this research would indicate that

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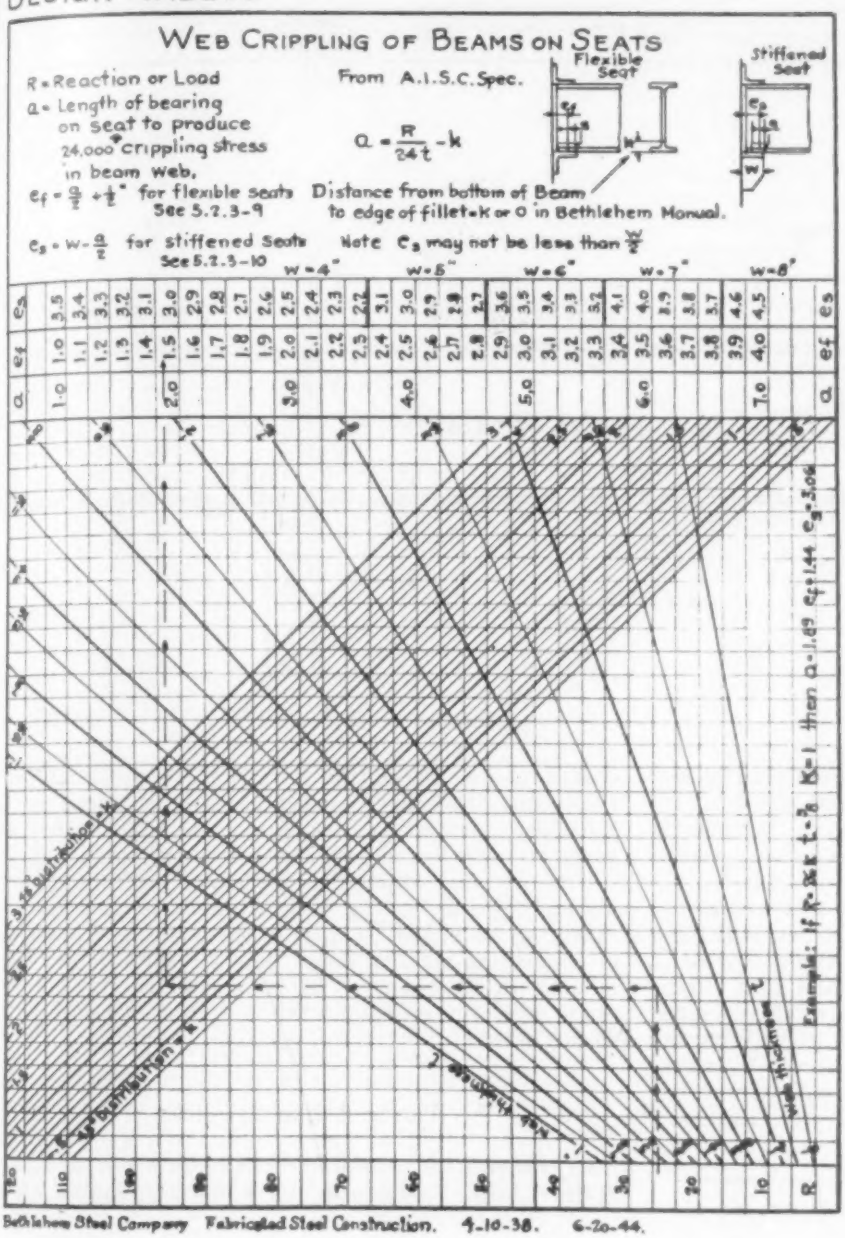

WEB CRIPPLING OF BEAMS ON SEATS
R = Reaction or Load
a = Length of bearing on seat to produce 24,000# crippling stress in beam web.
From A.I.S.C. Spec.
Flexible Seat
Stiffened Seat
Distance from bottom of Beam to edge of fillet = K or O in Bethlehem Manual.
See 5.2.3-9
See 5.2.3-10
Note C_3 may not be less than
w=4"
w=5"
w=6"
w=7"
w=8"
Example: If R = 36k t = 1/2 K = 1 then a = 1.69 C_f = 1.44 C_s = 3.06
Bethlehem Steel Company Fabricated Steel Construction. 4-10-38. 6-20-44.

Fig. 1

the most satisfactory connections for primary beam-column connections are those employing a seat, together with some form of top connection. Even seated connections with top plates of such limited dimensions as to greatly restrict ductile action were found to have better characteristics than most of the other types of joints tested. Connections employing direct welding of beam web to column (Figs. 2, 3), or employing side plates to eliminate milling beams to length (Figs. 3, 4), or using a single side angle shop welded to the beam and field butt welded to the column (Figs. 5, 6), were all found to provide too high initial rigidity and too low an ultimate strength for primary connections where normal rotation is required. A comparison between Figs. 5 and 6, and 7 and 8, however, would indicate this connection may be suitable for small beams with thin webs, when the load is small enough that the connection need be no more than one-half the depth of beam.

Seated connections employing small side plates or side angles welded in such a manner as to restrict ductile action were also found to have too high initial stiffness and too low an ultimate strength (Figs. 9, 10, 11).

A tee type connection (Figs. 12, 13) was found to have better all-around characteristics because of the flexing of the tee flange under load. Certain recommendations were made for improving the detail but it has not yet been considered worthy of further research.

Some spandrel connections were tested, using plates (Fig. 14), crimped plates (Fig. 15), plates and fills (Fig. 16) and a seat and top angle (Fig. 17). Figure 18 indicates that the plate types were all fairly satisfactory, though when a crimped plate is used the straightening of the crimp at the top when the beam is loaded causes a lateral displacement or torsional effect at the end of the beam that must be taken into account. Figure 19 indicates that the connection of Fig. 17 has somewhat the same characteristics as those of Figs. 9 and 10, an indication that the top angles are not so located that deformation of connection material may permit end rotation with safety.

The fine results indicated in Figs. 20, 21 and 22 for top plates led to a further investigation on Top Plate and Seat Connections[9] which indicated this type connection may be designed to serve in rigid, semirigid or flexible joints.

The Question of End Restraint

A whole series of investigations[10–16] have been made on continuous frames and their joints, demonstrating the savings in material possible with rigid and semirigid joints as against the conventional assumption of simple span action. While a good case has been made for material saving, there is still some doubt as to the over-all economic advantage of semirigid and rigid construction.

Some more work is necessary to develop rigidity factors for frame analysis from the connection values already established and the contributing factors of column flange stiffness, the effect of stiffeners and adjoining connection material.

No attempt will be made to go into this field except to state certain incidental facts bearing on the general subject of welded details. A study of the moments in beams with various degrees of end restraint (Fig. 23) indicates that probably the most efficient framing will be achieved when the connection and beam are designed for about 87½% rigidity, a reasonable assumption indicated by the moment-rotation curves for seat and top-plate connections[9] (Figs. 24, 25). It will be noted that while any falling off in connection rigidity down to say 62½%, due to lack of stiffness in the column material or similar cause, would increase the beam center moment as the end moment decreased, there would be no increase in the maximum or beam-design moment. Should the connection develop a higher restraint than contemplated in the design, it would merely result in reducing the center moment. The consequent increase in end moment is of

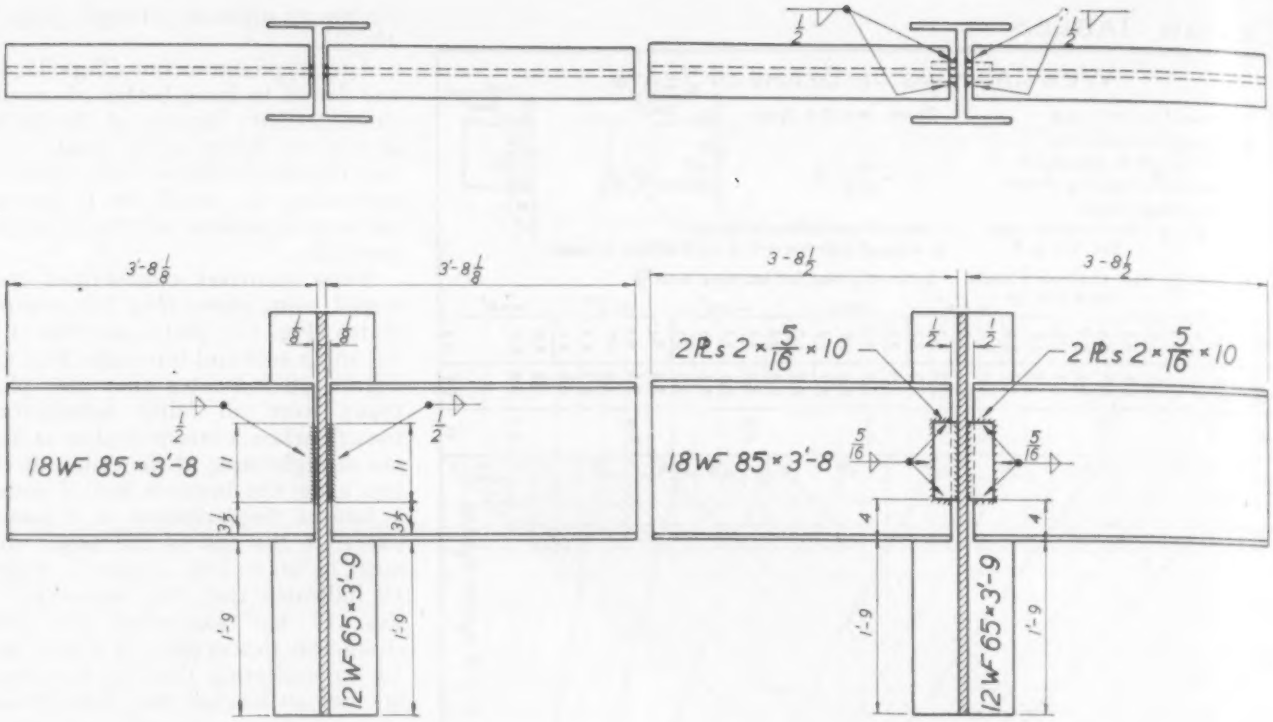


Fig. 2—Test W1

Fig. 4—Test W5

little concern, for the development of yield point stress in the connection acts to reduce the end moment, re-establishing a more balanced stress condition. Of course, it is assumed that the joint has been properly designed to permit such ductile yielding.

It is then reasonable to assume that a structure designed on the assumption of full continuity will have joints whose true rigidity may be in the vicinity of 90%, resulting in an actual capacity in excess of that anticipated in the design. It is the utilization of this increase in capacity under decreased joint rigidity which intrigues the exponents of semirigid structures. However, as previously stated, it is not yet definitely determined whether the saving in material is sufficient to offset the increased cost of design. Also, this discussion has dealt only with the beams; the effect upon the columns must also be considered, and where the columns are light much of the beam saving is lost in increased column moment.

The preceding discussion applies to loadings approximating uniform loading; Fig. 23 indicates that for concentrated loads at the center of the beam, any reduction in connection rigidity below 100% results in increased moment in the beam. The designer must therefore arrange his framing to avoid this condition of loading if he wishes to take advantage of semifixed connections.

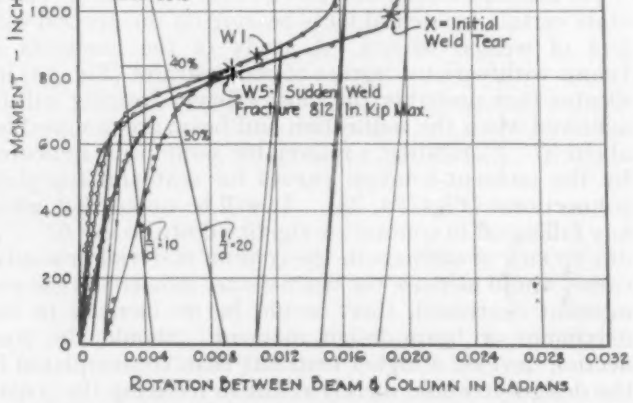


Fig. 3—Moment-Rotation Curves for Tests W1, W3 and W5

Plastic Action in Details

At this point it is desirable to examine several clauses in the A.I.S.C. Specification for Welded Buildings, which

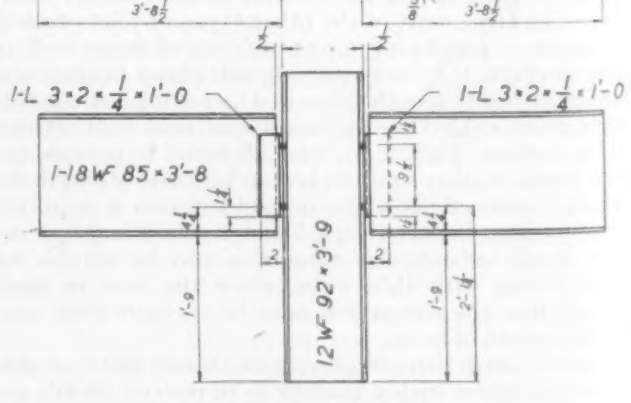


Fig. 5—Test W 13

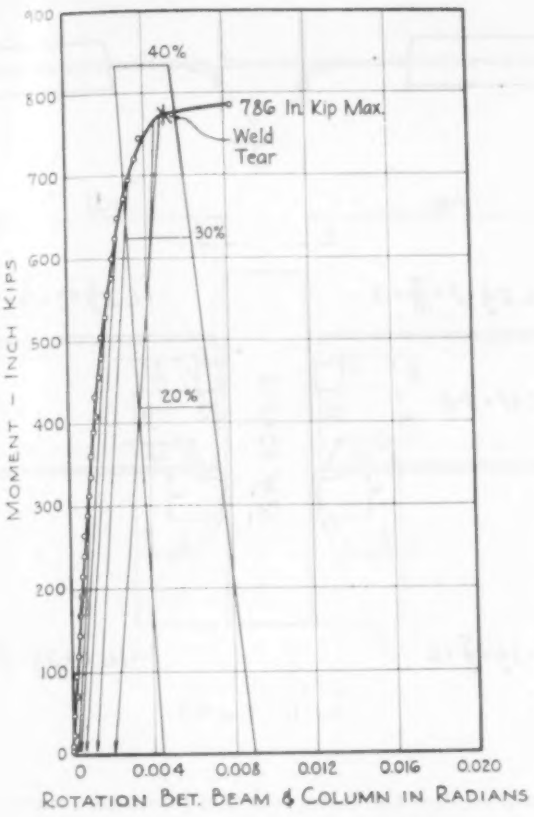


Fig. 6—Moment-Rotation Curve for W13

introduce new concepts in structural design, vital to any consideration of welded details.

The Specification lists three types of construction, Type 1, rigid frame, assumes connections sufficiently rigid to hold virtually unchanged the original angles between the various members. Type 2, conventional or simple framing, assumes the members connected for shear only and the joints free to rotate under load. Type 3, semirigid, assumes the joints to possess dependable and known moment capacity intermediate between Types 1 and 2 construction. The Lehigh University Researchers[8, 9] recommend that connections for Type 1 construction should develop not less than 90% rigidity, for Type 2 construction not over 20% and for Type 3 from 20 to 90% rigidity (Fig. 26).

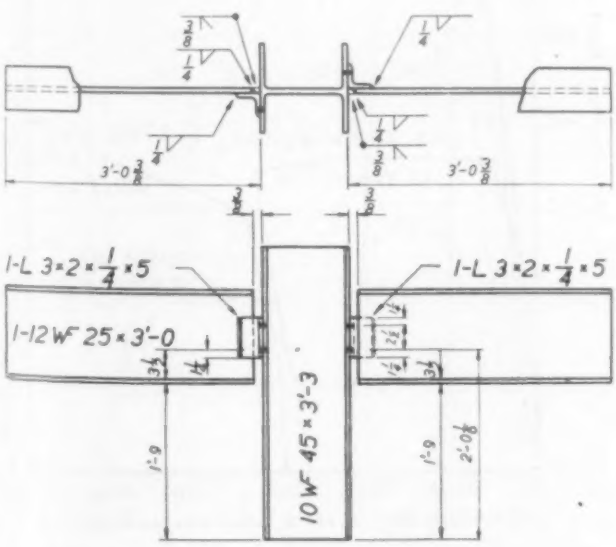


Fig. 7—Test W16

The Specification also provides "In tier buildings designed in general as Type 2 construction, in that the beam to column connections other than wind connections are flexible, the distribution of wind moments, as between the several joints of the frame, may be made by a recognized empirical method provided that either:

"1. The wind connections, designed to resist the assumed wind moments, are adequate to resist the moments induced by gravity loading and the wind loading, at the increased unit stresses permitted therefor, or,

"2. The wind connections designed to resist assumed wind moments, are so designed that larger moments induced by the gravity loading under the actual conditions of restraint will be relieved by deformation of the connection without overstress in the welds."

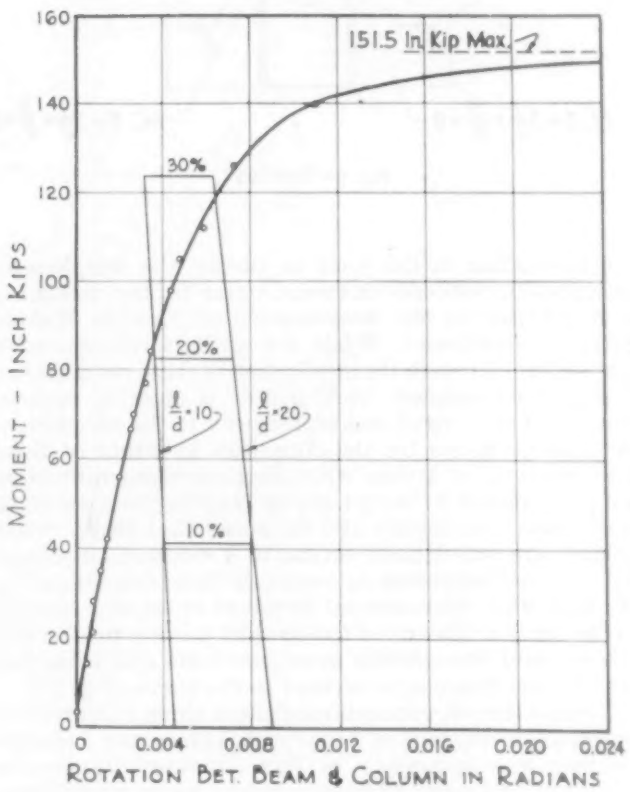


Fig. 8—Moment-Rotation Curve for W16

Also "Types 2 and 3 construction may necessitate some nonelastic but self-limiting deformation of a structural steel part, but under forces which do not overstress the weld."

The idea of designing a joint to yield under certain combinations of forces is disturbing to some engineers, though this has been a common if little publicized virtue of many common riveted details. The common top angles and framing angles of riveted construction are subjected to as severe deformations as similar welded details. The difference is only that experience has taught that rivets are strong enough in tension to resist the bending forces involved while it has been thought that similar action in a welded detail would create excessive stress at the root of the fillet weld.

However, such is not the case, since the connections are not free to rotate without limit. The deformation of the angle leg, when flexible angles are used, permits suf-

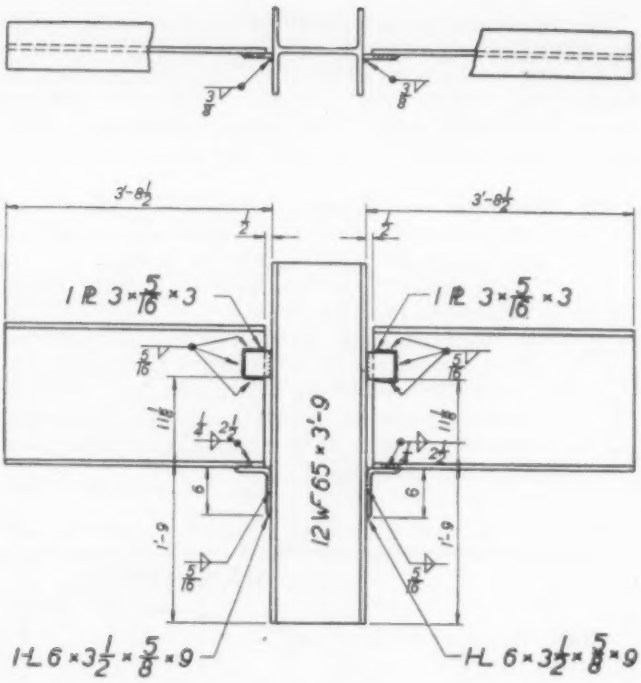


Fig. 9—Test W7

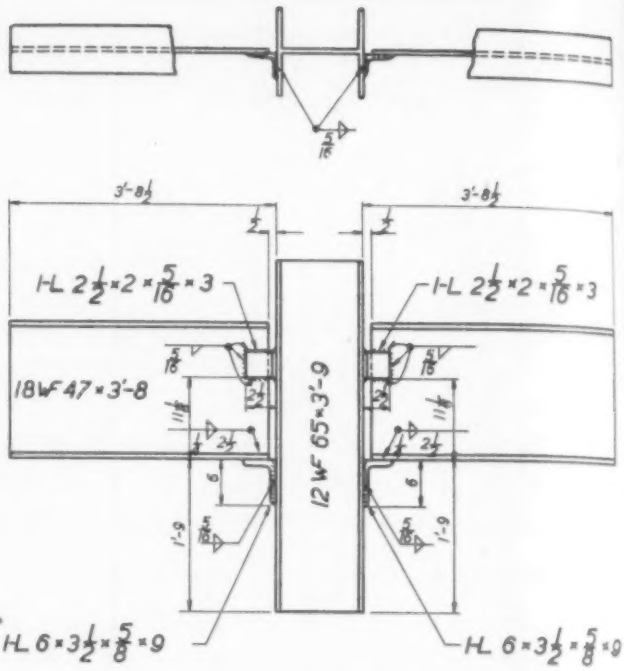


Fig. 10—Test W8

ficient rotation in the joint to justify the simple-span assumption, without excessive stress in the welds, as demonstrated in the investigation of Flexible Welded Angle Connections.[7] While the authors recommended certain limitations in the application of these connections, based on an assumed "yield point," it must be remembered that this report was issued prior to the adoption of the above clauses by the American Institute of Steel Construction, at a time when Engineers generally were not conditioned to accept plastic yielding in a strength connection. It should also be noted that these "yield points" are not definite breaks in a stress-strain curve, but are artificial points on a smooth curve determined by the somewhat conventional device of drawing a tangent to the curve at the end of the straight portion to intersect a horizontal through the maximum load, and from this intersection dropping a vertical to the curve (Fig. 27).

Tests of flexible connections showed three to four times simple-span rotation of beam ends before any inelastic yielding was apparent; in fact, framing connections could not be loaded to failure, but at six to seven times design rotation the lower flanges began to bear, a condition which tends to increase the strength of the joint. In the straight tension tests the angles with $3^1/_2$-in. legs failed at 1.6 in. while the 4-in. legs failed at 1.98 in. as compared to the suggested limits of 0.08 and 0.1 in., respectively, a ratio of 20 to 1. It must also be remembered that in an actual structure the deformation of these angles is a function of the beam deflection, which is self limiting in the sense that rotation is limited to the end slope corresponding to free-ended deflection. Figures 28 and 29 show the degree of flexing in the straight pull tests, Figs. 30 and 31 show the full-size beam tests and Fig. 32 gives the test data for the beam connections.

Design Procedure for Framing Angles on Beam Webs

Figure 33 is a design chart for framed connections. The proposed standard formula for the design of the field welds is shown on this figure, as well as a diagram indicating the assumptions upon which the design is based. It is assumed that the beam reaction produces a moment in the weld which is equal to $Re/2$. The shear in this weld is $R/2L$. It is assumed that the neutral axis is one-sixth the distance from the top of the weld, and that the distribution of stress is triangular. The tensile and compressive forces are then $2L/3$ apart and equal

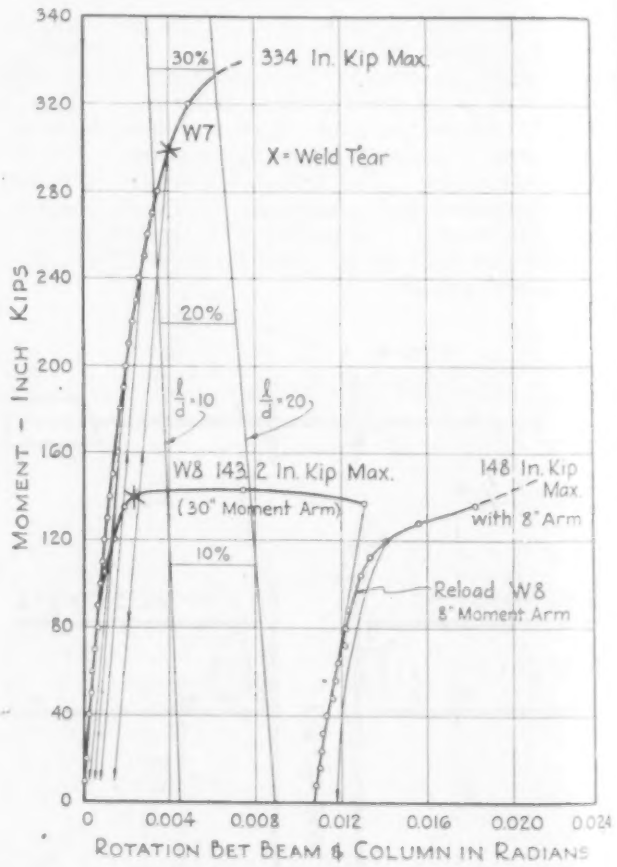


Fig. 11—Moment-Rotation Curves for Tests W7 and W8

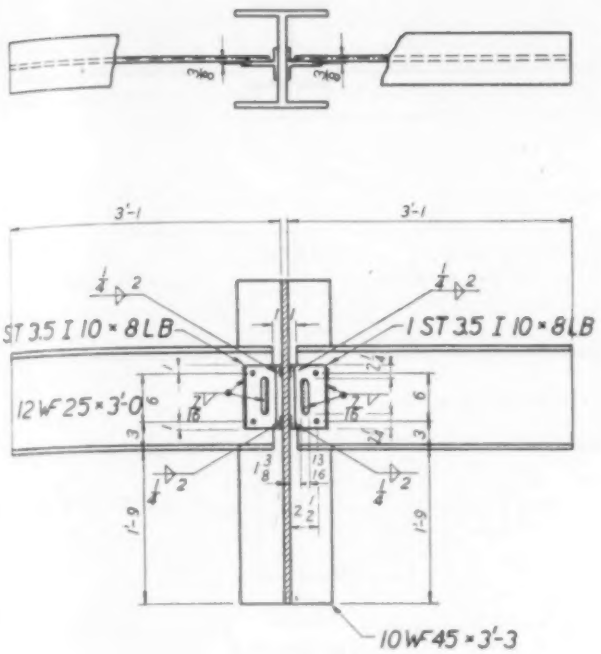


Fig. 12—Test W9

$$\frac{Re}{2} \div \frac{2L}{3} = \frac{3Re}{4L}$$

If the total tension is $3Re/4L$ the tension in the extreme fiber is

$$\frac{3Re}{4L} \div \left(\frac{5L}{6} \times \frac{1}{2}\right) = \frac{9Re}{5L^2}$$

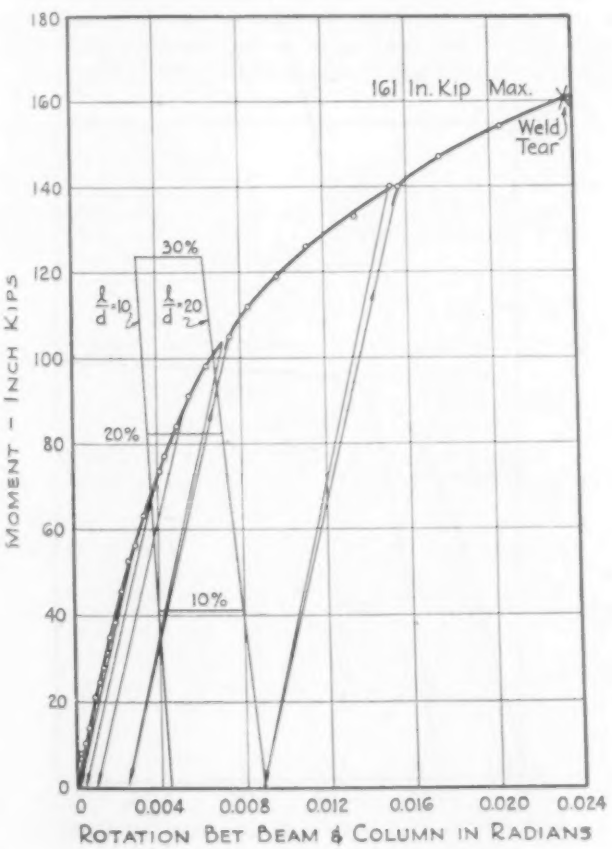


Fig. 13—Moment-Rotation Curve, Test W12

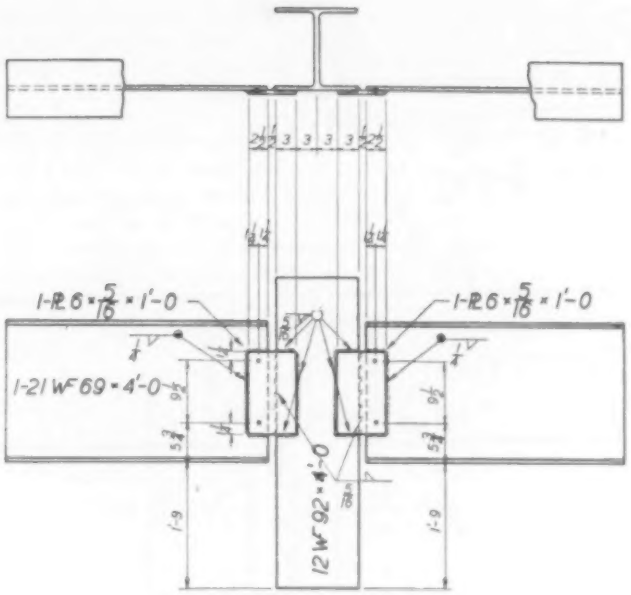


Fig. 14—Test W18

The resultant stress then is

$$f = \sqrt{\left(\frac{R}{2L}\right)^2 + \left(\frac{9\ Re}{5L^2}\right)^2} = \frac{R}{2L}\sqrt{1 + \left(\frac{3.6e}{L}\right)^2}$$

Substituting for f its value $(13.6 \times 0.707) = 9.6D$ kips per square inch and solving for the reaction gives

$$R = \frac{19.2LD}{\sqrt{1 + \left(\frac{3.6e}{L}\right)^2}}$$

A similar analysis by Malcolm Priest[17, 18] assumes the neutral axis one-tenth the distance from the upper end of the weld, while Gilbert Fish[19] assumes a point bearing at the top. The values determined by these three methods are not so far apart or so out of agreement with test results but that a committee could agree upon a reasonable assumption as to the location of the neutral axis, and announce a design method satisfactory to all concerned.

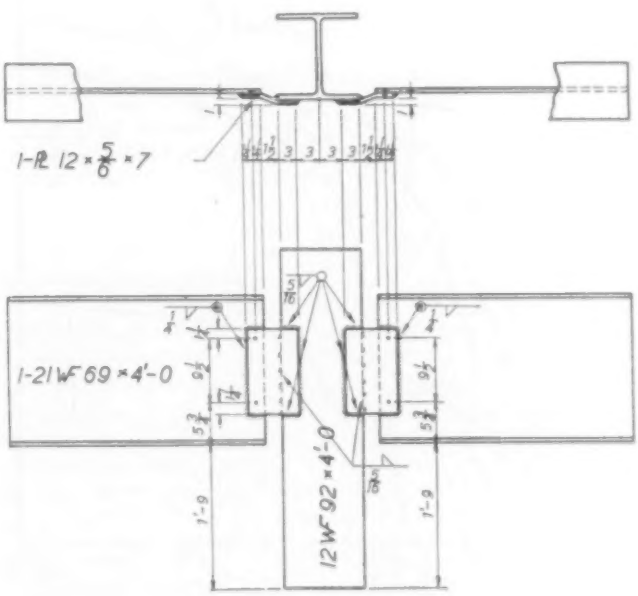


Fig. 15—Test W19

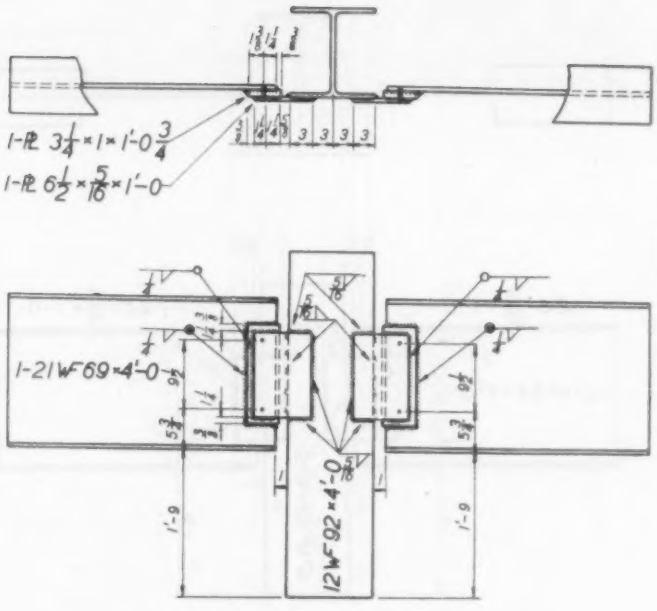


Fig. 16—Test W17

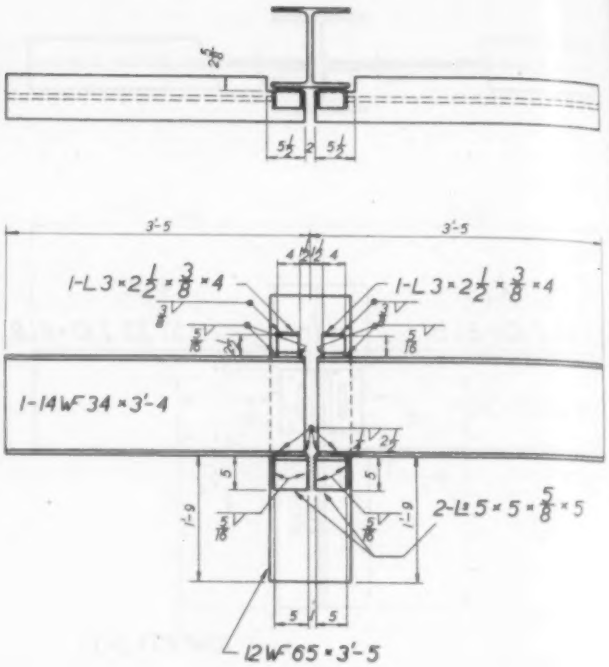


Fig. 17—Test W20

The shop welds against the web of the beam are designed on the assumption that the vertical reaction acts in the plane of the outstanding legs to produce a moment in the welds $Re'/2$. The sheer stress in each weld is

$$fs = \frac{R}{2(L + 4)}$$

for $2^1/_2$-in. angle leg, and the stress due to moment

$$fm = \frac{Re'}{2} \div \frac{\text{Polar I}}{d}$$

where d is the distance from the center of gravity of the weld to the extreme fiber. The resultant may not exceed 9.6 kips per square inch. Priest[17, 18] offers a solution based on a 3-in. leg, and a general equation for the combined stress in such a weld is given by Fish[19, 20] in the 1938 A.W.S. *Handbook*. Curves for the solution based on this formula are given in Fig. 34.

It will be found that for angle lengths 18 in. or less, the field weld determines the capacity when the shop weld is made $^1/_{16}$ in. smaller than the field weld. For longer angles the shop weld must be increased to the same size as the field weld, or the capacity must be determined from Fig. 34 instead of Fig. 33.

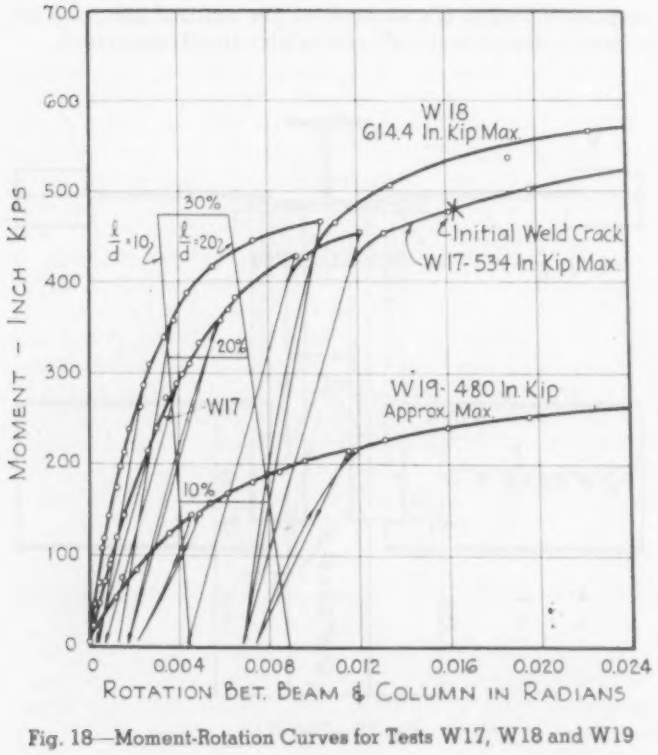


Fig. 18—Moment-Rotation Curves for Tests W17, W18 and W19

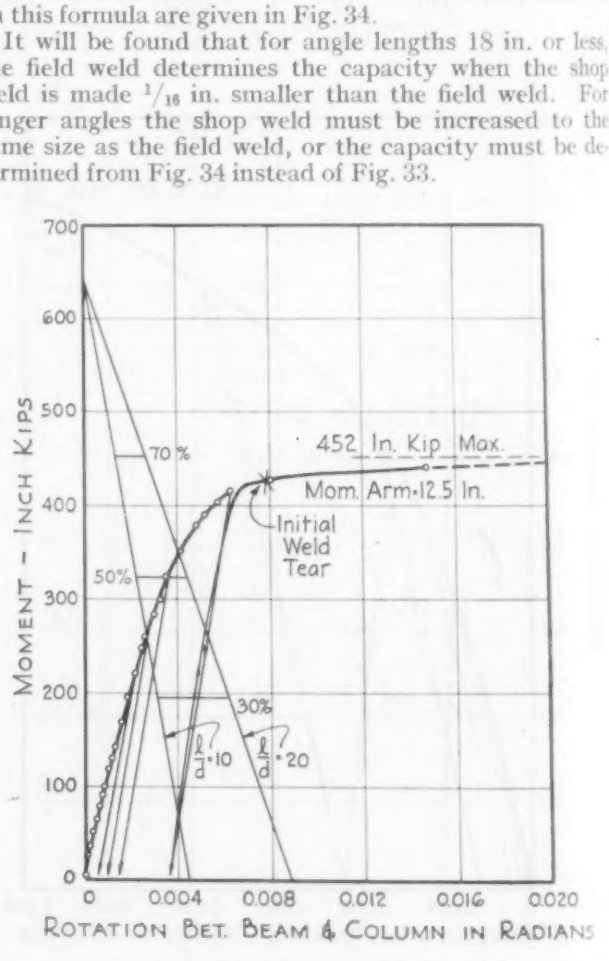


Fig. 19—Moment-Rotation Curves for W20

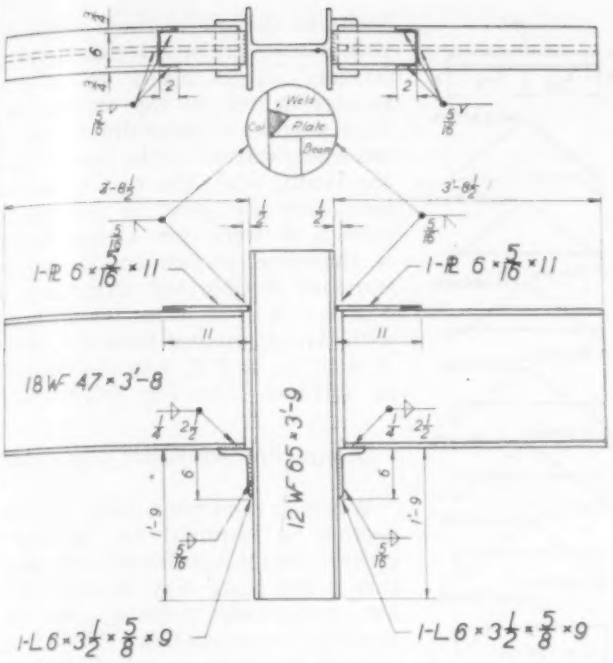


Fig. 20—Test W10

The return at the top of the field weld is not included in the design of the joint. It is added to assure a good weld without craters at this critical point, and for its effect on creep under repetition of loadings. It is extremely important that the length of this return be no greater than one-quarter the angle leg, or it will unduly restrict flexibility. For the same reason any erection bolts in these angles should be placed as low as possible to preclude any possibility of interference with flexing of the angle.

The tests were made on $^1/_4$-in. thick angles with $3^1/_2$-in. outstanding legs, using $^1/_4$-in. fillets. Obviously any

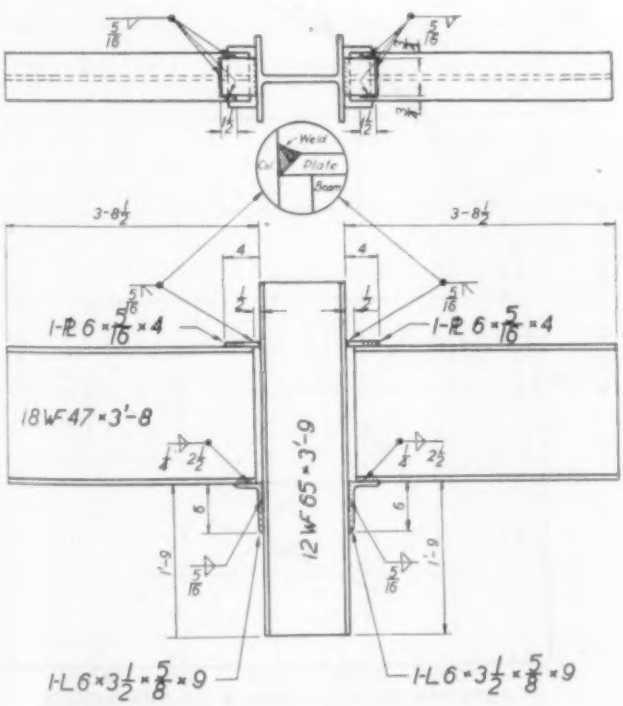


Fig. 21—Test W9

increase in angle thickness due to corrosive conditions or some similar reason, would necessitate an increase in width of leg to maintain the same relative flexibility. Since the flexibility decreases as the cube of the thickness and increases directly as the width, it is recommended that the angles be increased to $5 \times 3^1/_2 \times {}^5/_{16}$ and $7 \times 4 \times {}^3/_8$ respectively, for $^5/_{16}$ and $^3/_8$ thicknesses. Referring to Fig. 33, it will be found that the field welds also, must be increased to $^5/_{16}$ and $^3/_8$, respectively. The shop weld value is not reduced at the same rate, but for standardization purposes should be made $^1/_{16}$ in. less than the field weld.

While it has been considered good practice to limit this connection to two-thirds the depth of beam there is no reason why it should be so limited, since the angles have sufficient flexibility to function at greater depths. It is probable this practice originated in some early published

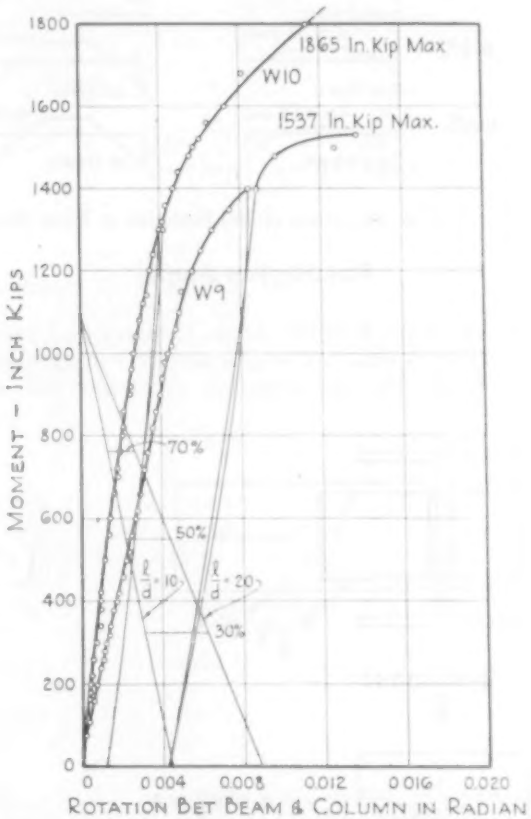


Fig. 22—Moment-Rotation Curves for Tests W9 and W10

article where the side angles were coupled with a similar connection using side plates, which had no flexibility and depended on beam web deformation to prevent weld failure. Obviously such a connection should be limited, but there seems to be no logical reason for limiting the length of the flexible angles.

The values of the standard framing connections need not be reduced because of the web thickness of either the connected beam, or the girder to which it connects. It has been contended[17, 18] that a condition exists, similar to riveted connections where the web thickness determines the bearing value of the rivets. Careful analysis, which considers the direction, as well as the magnitude, of all of the forces involved will show, however, that for framing connections, of the proportions contemplated as standard, the shear intensity in the vicinity of the connection welds may be ignored if the average shearing stress in the beam web does not exceed that permitted by the specifications.

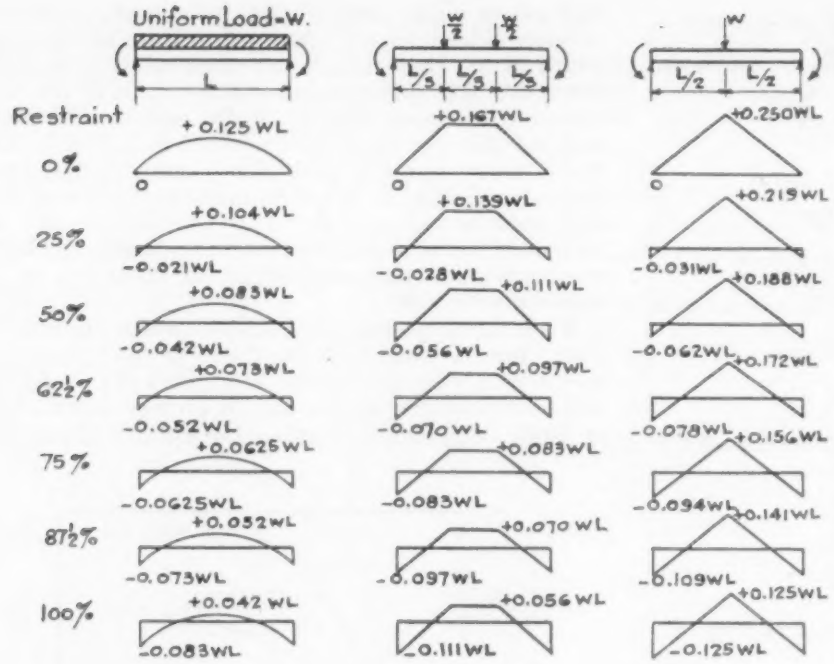


Fig. 23—Effect of End Restraint on Beam Bonding Moments

Flexible Top Angles

The report on Flexible Angle Connections[7] also covered tests on flexible top angles used in conjunction with seats. While the investigators recommended certain limits to the use of these angles, the points covered in the discussion on framing angles apply to an even greater degree to top angles, since their purpose is generally to prevent sidewise rotation of the top flange of the beam, while the seat carries the load and the joint is designed as though it were pin connected. It is, therefore, recommended that the standard flexible top angle be 4 × 4 × ¼ × 0 ft. 6 in. for all beams with flanges greater than 4 in. and 4 × 4 × ¼ × 0 ft. 4 in. for flanges 4 in. and less. (See Fig. 38.)

Design Procedure for Top Plates

Where a somewhat stiffer top connection is required to provide a greater nominal stiffness in the structure a top plate may be used, without necessarily passing over into semirigid construction. The design of such plates is described in the report on Top-Plate and Seat Connections.[9] The end of the plate is connected to the column by a butt weld designed to develop 25% of the resisting moment of the beam at 16,000 psi. tension. The plate is reduced in section as shown in Fig. 35 to one-half the width, to produce a unit stress in the narrow portion of 32,000 psi. The plate is attached to the beam flange by a continuous fillet weld across the end, and returning

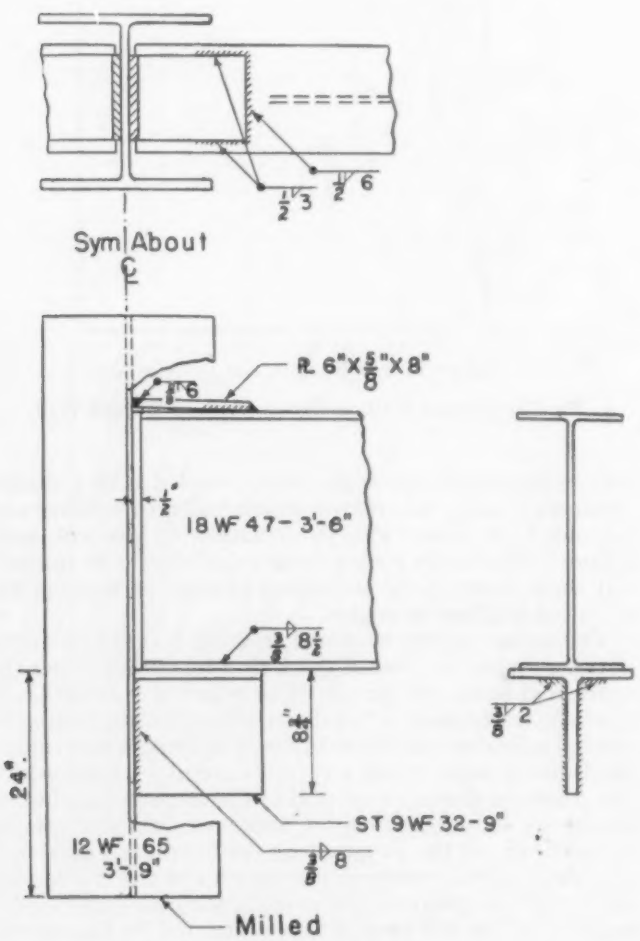


Fig. 24—Test 3

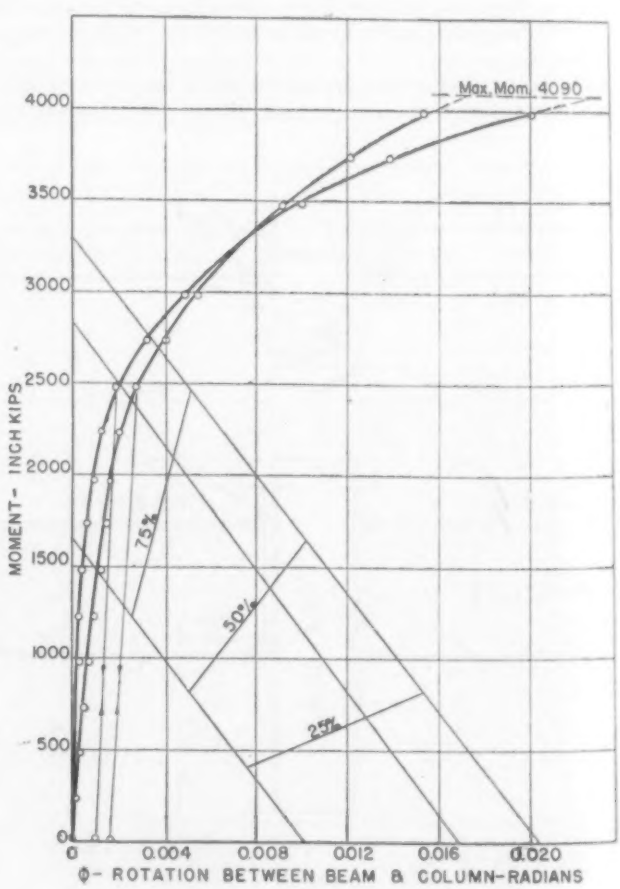


Fig. 25—Moment-Rotation Curves for Test 3

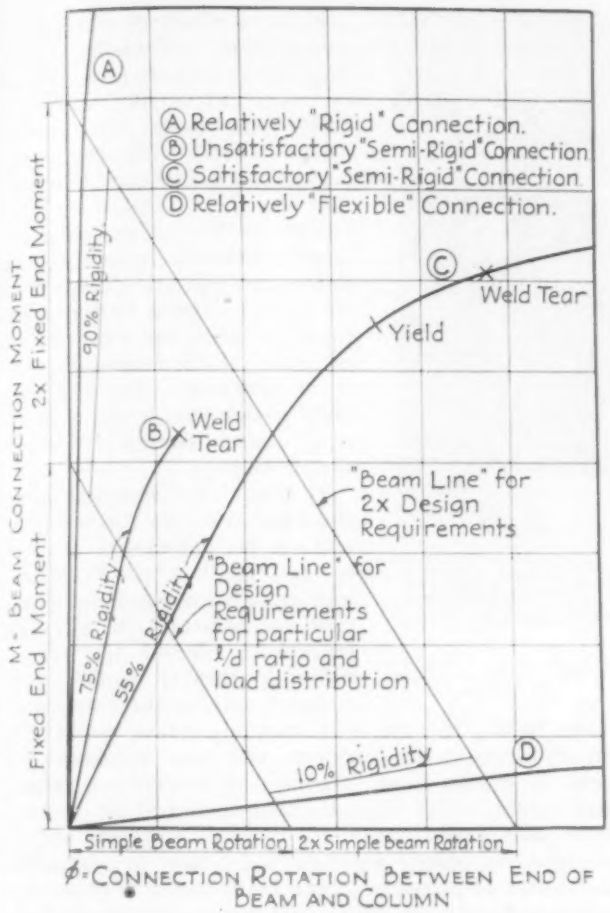

A Relatively "Rigid" Connection.
B Unsatisfactory "Semi-Rigid" Connection
C Satisfactory "Semi-Rigid" Connection
D Relatively "Flexible" Connection.
M = Beam Connection Moment
2x Fixed End Moment
Fixed End Moment
90% Rigidity
75% Rigidity
55% Rigidity
Weld Tear
Yield
Weld Tear
"Beam Line" for 2x Design Requirements
"Beam Line" for Design Requirements for particular l/d ratio and load distribution
10% Rigidity
Simple Beam Rotation
2x Simple Beam Rotation
ϕ = Connection Rotation Between End of Beam and Column

Fig. 26—Moment and Rotation Design Requirements for a Beam to Column Connection

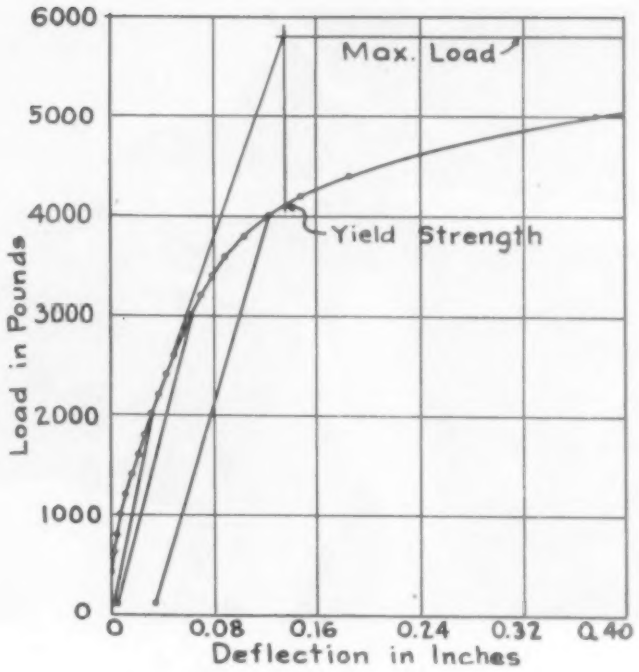


Fig. 27

on each side one-half to one times the plate width, to develop a value equivalent to the butt weld. The unwelded length of the narrow portion of plate should be made say 10 to 20% greater than the width, to assure ductile yielding.

The design of top plates for use in semirigid construction is also covered in the same report.[3] The plate is connected to the column for any desired moment at a value of 16,000 psi. in the butt weld, and to the top flange of the beam by fillet welds across the end with side returns one-half to one times the plate width, which should be 1 to $1^1/_4$ in. narrower than the beam flange. See Fig. 36. In this case the plate is made full width throughout, and the length between welds should again be made 10 to 20% greater than the plate width.

Since the plate is in this case of the same width as the butt weld, both are stressed to 16,000 psi., and the weld is not safer than the plate as in the previous case. The specimens of the report were designed for a moment equaling 75% of the capacity of the beam, but the method would be the same for any other moment between 100%, and say, 50%.

The back-up plate indicated in Fig. 37 should be used for all top-plate connections as the most practical method for obtaining full-strength butt welds in the field. Incidentally, back chipping is avoided by this method, eliminating the cost of taking such equipment into the field.

Design Procedure for Beam Seats

The investigation on welded seat angles was in two parts, a photoelastic study[4] and as tests of steel seats,[5] the conclusions of the two studies being in fair agreement. The general conclusions are that the strength of a seat angle varies roughly as the square of the thickness, inversely as the effective lever arm of the reaction, and is influenced by the length of vertical leg and the size of weld. Vertical shear has little effect on strength of weld unless the angle is thick enough to reduce bending in the vertical leg appreciably; even then the critical area is at

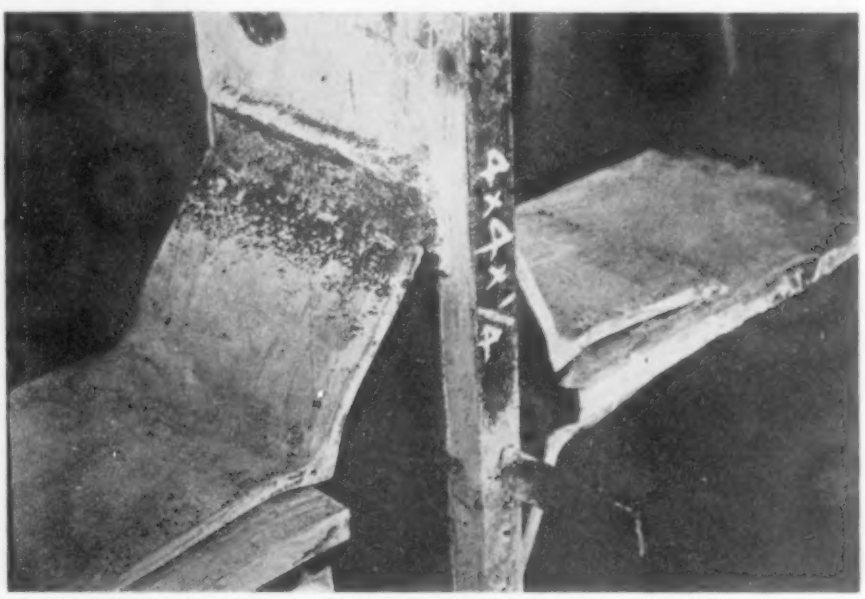


Fig. 28

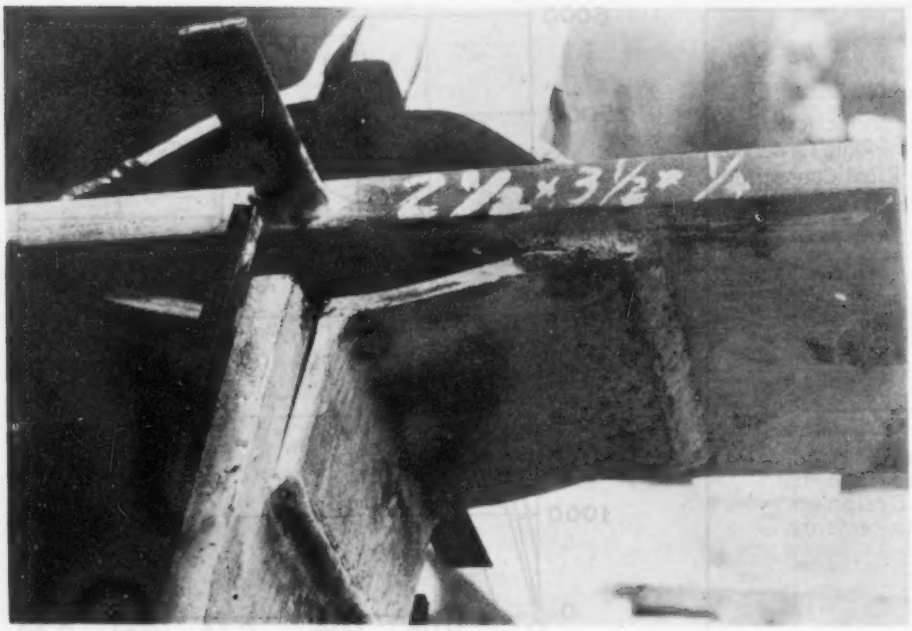


Fig. 29

the top of the weld and the neutral axis is above the mid-height of the welds. The horizontal leg of the angle acts as a cantilever with the critical section near the fillet of the angle. The length of weld does not markedly affect the strength, the length required being only slightly greater than that required for shear. The failure of a welded seat is gradual, the weld generally tears and allows the seat to move outward and downward, unless the lever arm is so short as to result in shear failure. These findings are greatly condensed from the two reports, and anyone wishing to study the design of this connection should go to the original papers for more complete information.

The method of designing seat angle thickness based on yield point stress at the fillet, used in the report,[3] agrees with that proposed by Malcolm Priest[17,18] and is based on the assumption that it is necessary that the angle yield under the design load if it is to assume the end slope of a simple beam.

It should be obvious that the shear intensity in the beam web will not be distributed according to the formula $a = (R/24t) - k$ unless the beam seat is sufficiently rigid to maintain this stress distribution. Should the seat be infinitely thin it would provide support only at the extreme end of the beam, and the unit crippling stress would be infinitely large. If, however, the seat is designed to yield at design load, a condition somewhere between that produced by an adequate seat and an infinitely weak seat results. As the load is applied, and the condition of plastic yielding in the seat is approached, the center of pressure of the load, which is common to both beam and seat, shifts toward the support until equi-

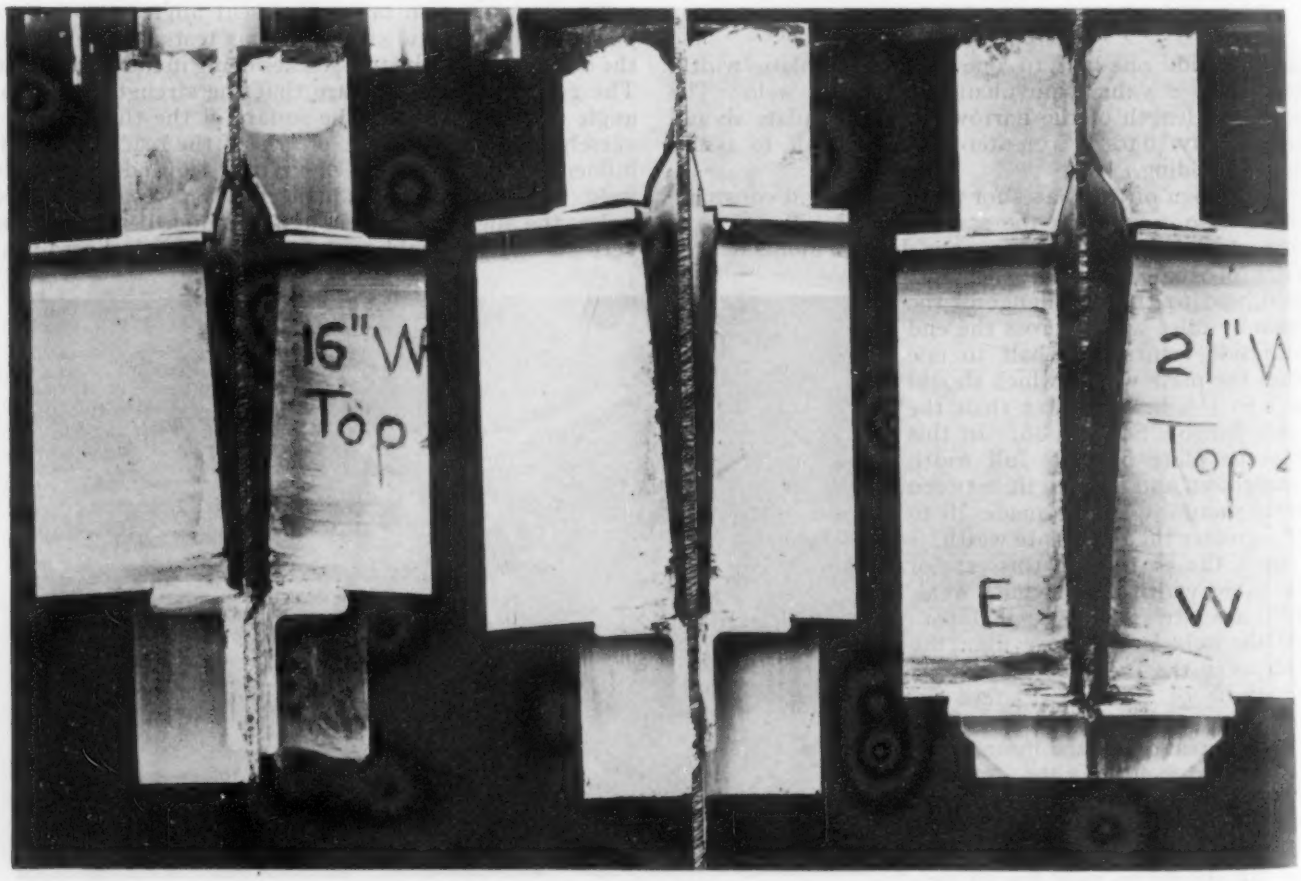


Fig. 30

librium is reached, the exact point being determined by the variables of load, beam web resistance and seat angle flexibility. As the force shifts, the moment in the seat is reduced, and the distribution of stress in the beam web changes from rectangular to trapezoidal; in extreme cases triangular. This results in an increase in the unit stress intensity in the beam web, which is maximum at the end of the beam.

No research has been conducted to determine the relative stresses in beam web and seat angle, as they are affected by this interplay of stresses, but an examination of the data of the "B" Series of the report,[5] and an examination of Fig. 41, seems to indicate that web crippling stresses become excessive when the seat is designed to yield at design loads. While the investigators attribute the crippling of the beam web to the extreme thickness of web, it should be obvious that a thicker web should increase the strength, not decrease it, if the seat is adequate to distribute the load.

It is reasonable, then, to assume, that if the unit stress in the critical section of beam web is not to exceed 24,000 psi., that the maximum bending stress in the seat should be some comparable value, say 20,000 psi.

Design of Flexible Seats

The design of flexible seats indicated on Fig. 38 is based on determining the center of loading from the web crippling formula (see Fig. 1); designing for bending in the angle limited to 20,000 psi. tension in the top of the seat over the edge of the fillet; assuming a constant end distance of $1/2$ in. between end of beam and the support, and a constant fillet radius of $3/8$ in. The heavier angles resulting from these assumptions reduce the stress in the beam web, reduce the stress concentration at the top of the weld by decreasing the tendency to rotation around the root of the fillet in the vertical angle leg, and increase the value of the weld, which increases as the square of the angle thickness. See Fig. 39 and the discussion on this point in the report.[5]

The distribution of stress in these welds is assumed by Priest[17, 18] to be triangular, with the neutral axis at the mid-height. Bruce Johnston in a report on Continuity in Welded Frames[14] developed a design method for seat angles based on the report.[5] He accepted Priest's assumption that the angle should yield under design load, but assumed a rectangular stress distribution with the neutral axis one and one-half times the angle thickness below the top of seat, a justifiable assumption for so flexible a seat.

The recommended design method of Fig. 38 assumes triangular stress distribution with the neutral axis two-thirds down from the top, based on the usual action of brackets connected through flexible elements tending to move the neutral axis toward the compression area. While the report does not indicate such action, seats designed by this method show fair accord with test results, as was demonstrated by a discussion on the report by the author in June 1935.[21] In this discussion it was shown that those specimens whose dimensions satisfied the proportions of the author's design showed a factor of safety with respect to weld yield ranging from 1.7 to 2.3 averaging 2. The factor of safety against angle yield was 1.2 to 2, averaging 1.5, whereas the design assumption of Priest and Johnston is based on angle yielding at design load.

Assuming a 14 in. WF 30 lb. with a reaction of 18 kips and designing the seat from the design charts of Priest, Johnston and Fig. 38 gives angle sizes 6 x 4 x $1/2$, 4 x 4 x $1/2$ and 5 x $3\frac{1}{2}$ x $1/2$, respectively, all 8 in. long and $5/16$-in. fillets. A similar design for an 18 in. WF 47 lb. beam with 36 kip reaction gives 8 x 4 x $3/4$, 6 x 4 x $11/16$ and 7 x 4 x 1, respectively, all the same length and using $1/2$-in. fillets. This would seem to indicate that when the

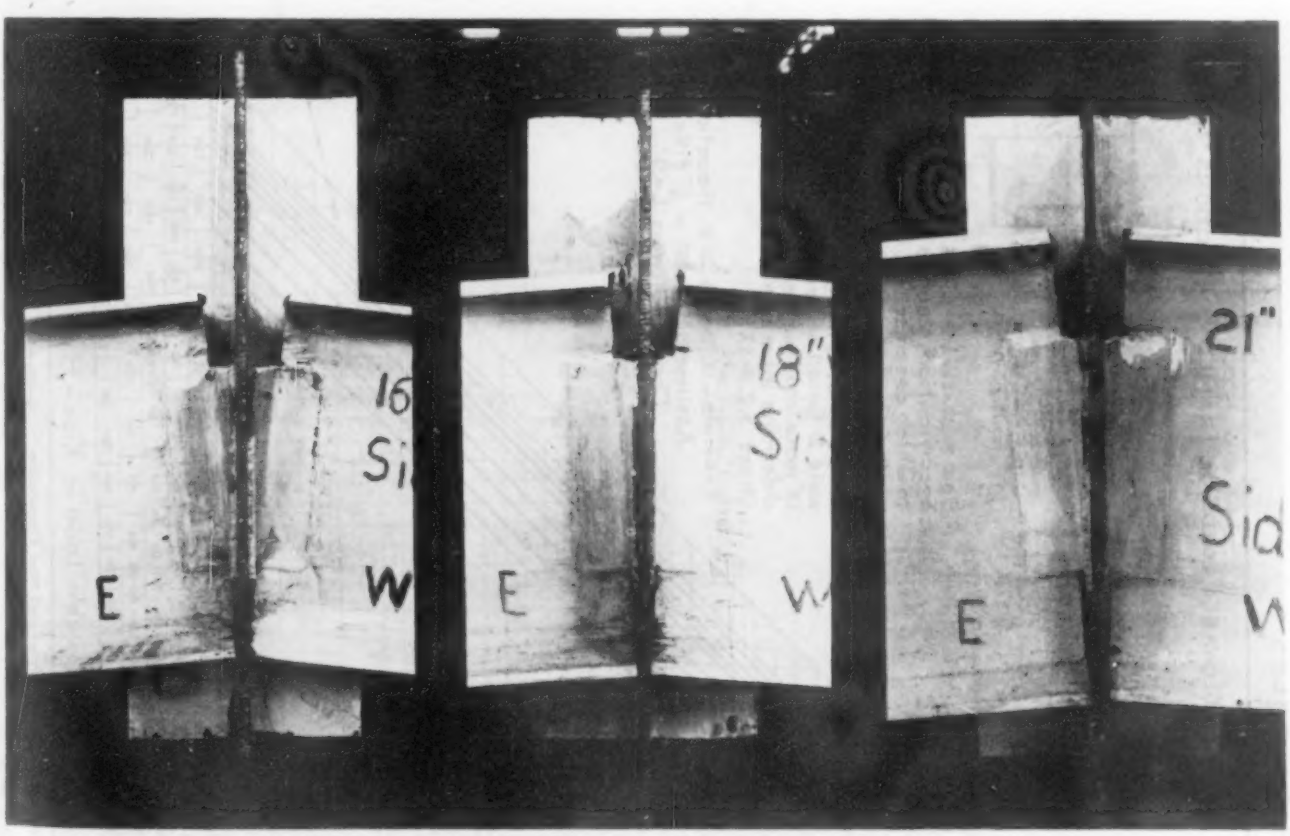
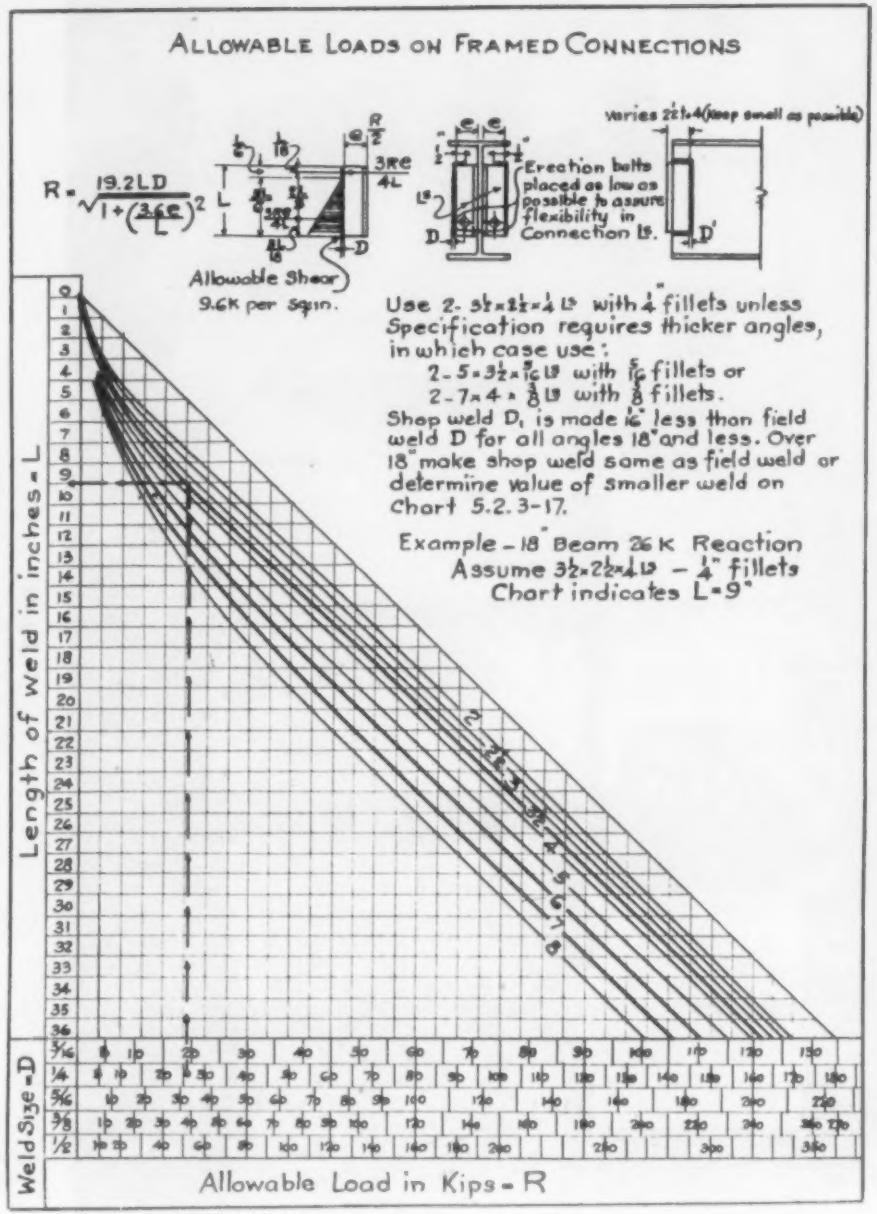
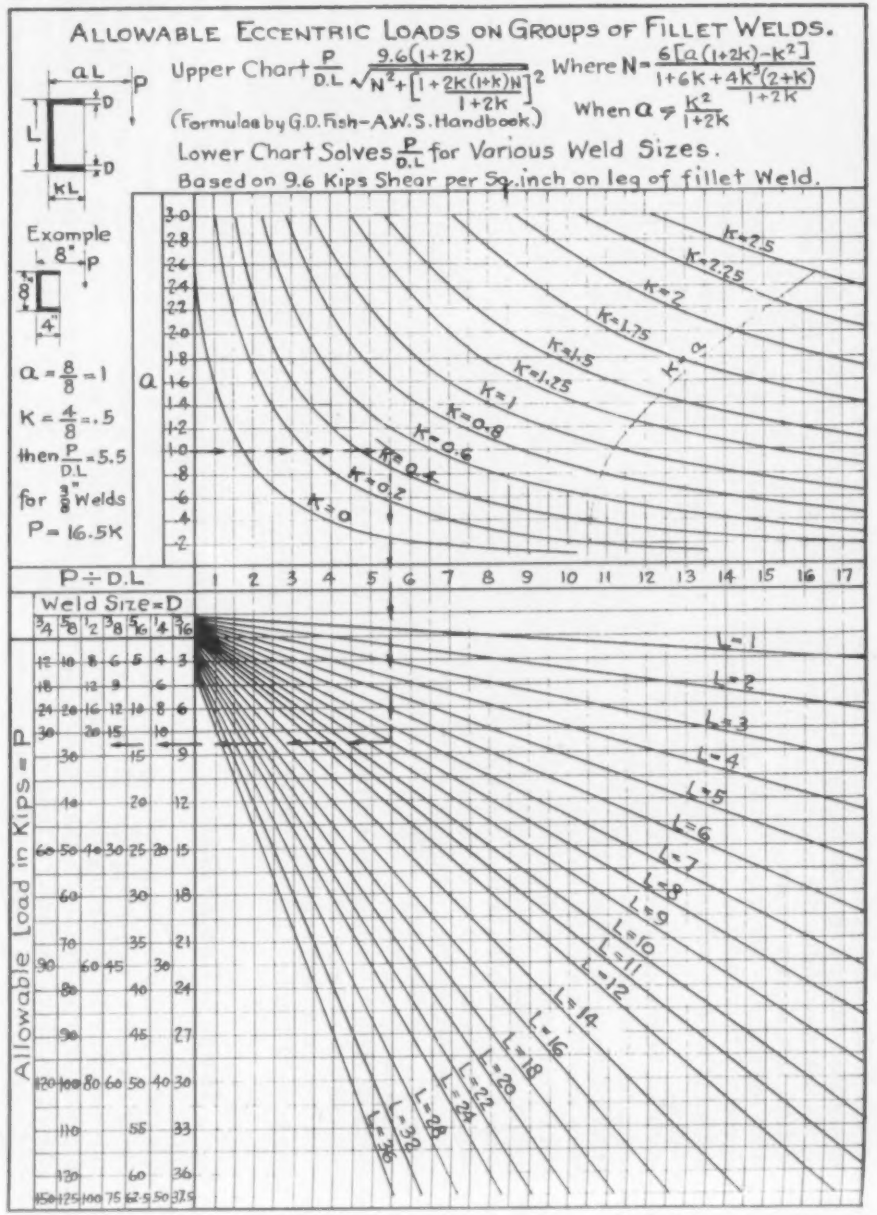


Fig. 31


ALLOWABLE LOADS ON FRAMED CONNECTIONS
R = 19.2LD / √(1+(3.6e/L)²)
Allowable Shear 9.6K per sqin.
Erection bolts placed as low as possible to assure flexibility in Connection L5.
varies 2½-4 (keep small as possible)
Use 2-3½×2½×¼ L5 with ¼" fillets unless Specification requires thicker angles, in which case use:
2-5×3½×5/16 L5 with 5/16 fillets or
2-7×4×⅜ L5 with ⅜ fillets.
Shop weld D1 is made 1/16" less than field weld D for all angles 18" and less. Over 18" make shop weld same as field weld or determine value of smaller weld on Chart 5.2.3-17.
Example - 18" Beam 26K Reaction
Assume 3½×2½×¼ L5 - ¼" fillets
Chart indicates L=9"
Length of Weld in inches = L
Weld Size = D
Allowable Load in Kips = R

Bethlehem Steel Company—Fabricated Steel Construction 6-20-44

Fig. 33


ALLOWABLE ECCENTRIC LOADS ON GROUPS OF FILLET WELDS.
Upper Chart P/D.L = 9.6(1+2K) / √(N² + [1+2K(1+K)N/(1+2K)]²)
Where N = 6[a(1+2K)-K²] / (1+6K+4K³(2+K)/(1+2K))
When a = K²/(1+2K)
(Formulas by G.D. Fish - A.W.S. Handbook)
Lower Chart Solves P/D.L for Various Weld Sizes.
Based on 9.6 Kips Shear per Sq. inch on leg of fillet Weld.
Example
a = 8/8 = 1
K = 4/8 = .5
then P/D.L = 5.5
for ⅜" Welds
P = 16.5K
P ÷ D.L
Weld Size = D
Allowable Load in Kips = P

Bethlehem Steel Company—Fabricated Steel Construction 3-3-39. 5-29-44

Fig. 34

Web Angle Connections			Top and Seat Angle Connections			
20	19	18	17	16	15	Test No.
$3\frac{1}{2}\times3\frac{1}{2}\times\frac{7}{16}\times11$	$3\frac{1}{2}\times3\frac{1}{2}\times\frac{7}{16}\times10$	$3\frac{1}{2}\times3\frac{1}{2}\times\frac{7}{16}\times9$	$4\times4\times\frac{7}{16}\times6$	$4\times4\times\frac{7}{16}\times6$	$4\times4\times\frac{7}{16}\times6$	Top Angle
Web A	Web A	Web A	10" long	$6\times4\times\frac{7}{16}\times8$	$7\times4\times\frac{7}{16}\times8$	Seat Angle
12WF65	12WF65	12WF65	12WF65	12WF65	12WF65	Column
21WF59	18WF55	16WF36	21WF59	18WF55	16WF36	Beam
35,200	ALL 28,000	MOMENTS 9,900	IN INCH 61,600	POUNDS 56,600	46,200	Moment at First Repetition
0.00465	ALL 0.00500	ROTATIONS 0.00495	IN RADIANS 0.00430	0.00525	0.00420	East Beam — Rotation
0.00465	0.00525	0.00325	0.00485	0.00450	0.00505	West Beam — Rotation
400-1600	350-1400	150-600	700-2800	700-2800	700-2800	Load Range
50	50	50	50	50	50	No. Cycles
0.00010	0.00010	0.00025	0.00040	0.00035	0.00035	East Beam — Creep
0.00005	0.00015	0.00015	0.00035	0.00035	0.00015	West Beam — Creep
41,800	34,000	11,550	68,200	62,000	49,500	Moment at Second Repetition
0.00600	0.00670	0.00665	0.00590	0.00660	0.00600	East Beam — Rotation
0.00600	0.00695	0.00395	0.00675	0.00350	0.00740	West Beam — Rotation
475-1900	425-1700	175-700	775-3100	775-3100	750-3000	Load Range
50	50	50	50	50	50	No. Cycles
0.00020	0.00025	0.00020	0.00025	0.00060	0.00005	East Beam — Creep
0.00025	0.00020	0	0.00030	0.00045	0.00015	West Beam — Creep
48,400	36,000	13,200	72,700	66,000	59,400	Moment at Third Repetition
0.00775	0.00745	0.00800	0.00695	0.00810	0.00705	East Beam — Rotation
0.00780	0.00785	0.00445	0.00780	0.00660	0.00845	West Beam — Rotation
550-2200	450-1800	200-800	825-3300	825-3300	900-3600	Load Range
50	50	50	50	50	50	No. Cycles
0.00025	0.00020	0	0.00020	0.00065	0.00040	East Beam — Creep
0.00020	0.00010	0.00005	0.00030	0.00040	0.00005	West Beam — Creep
70,400	56,000	46,200	136,400	92,000	89,100	Moment — First Visible Crack in Return Weld, East Beam
0.01900	0.01760	0.02460	0.02675	0.01905	0.02340	Rotation — First Visible Crack in Return Weld, East Beam
70,400	56,000	46,200	145,200	92,000	82,500	Moment — First Visible Crack in Return Weld, West Beam
0.01810	0.01820	0.02115	0.03825	0.01635	0.02180	Rotation — First Visible Crack in Return Weld, West Beam
0.00610	0.00652	0.00600	0.00610	0.00652	0.00600	Design Rotation
0.03380	0.03035	0.03570	0.03165	0.04725	0.04560	East Beam — Max Rot.
0.03470	0.03060	0.03295	0.03825	0.03555	0.04380	West Beam — Max Rot.
88,000	68,000	56,100	145,200	128,000	103,900	Maximum Moment

Fig. 32

loads are small the variations in required angle thickness are less than the standard variations in angle thickness. The length of vertical leg of the author's design is in all cases midway between the results of the other two methods. It is reasonable to expect that seat angles designed by any of the three methods would be adequate to carry the load; however, for large loads and at points near the upper range of the various angle thicknesses of either Priest's or Johnston's design charts it may be expected that web crippling will result under design loads.

The author's design method was used for designing the seats used in the investigation of Miscellaneous Building Connections[8] and Welded Top-Plate and Seat Connections.[9] and exhibited no weaknesses. Where the top connection did not fail, ultimate failure generally occurred in web buckling preceded by web crippling over the seat; or if no stiffeners were used under the load, web crippling occurred at that point.

Another carry-over from riveted practice exists with respect to this type of detail, in that there are those who would limit the seat to a maximum reaction of 35 kips. If the seat angle is designed according to the proposed method there is no logic to such limitation. It is logical to set a maximum on a riveted angle seat without stiffeners, whose maximum of four rivets are designed for shear alone, but it is not logical to carry the arbitrary limits of such a detail over into a welded detail proportioned for the moments and shears to which it will be subjected, especially when research indicates that such connections have ample reserve beyond design requirements.

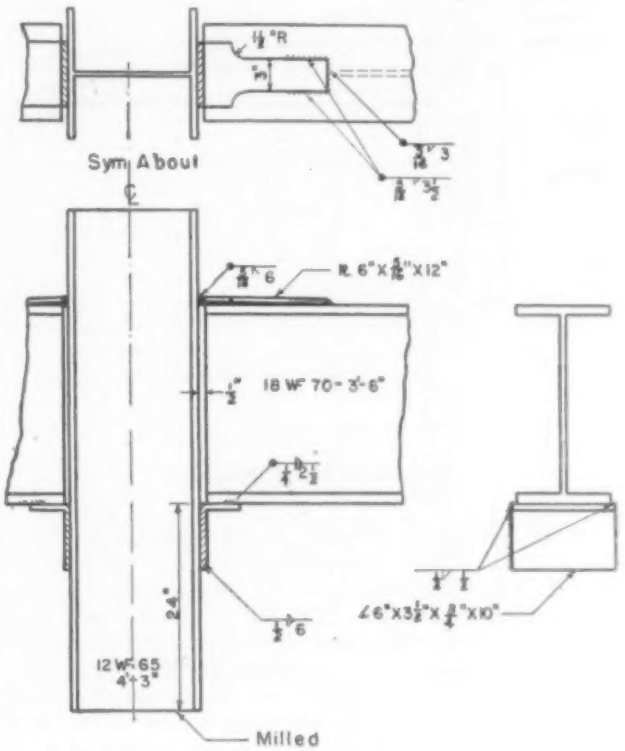


Fig. 35—Test 13

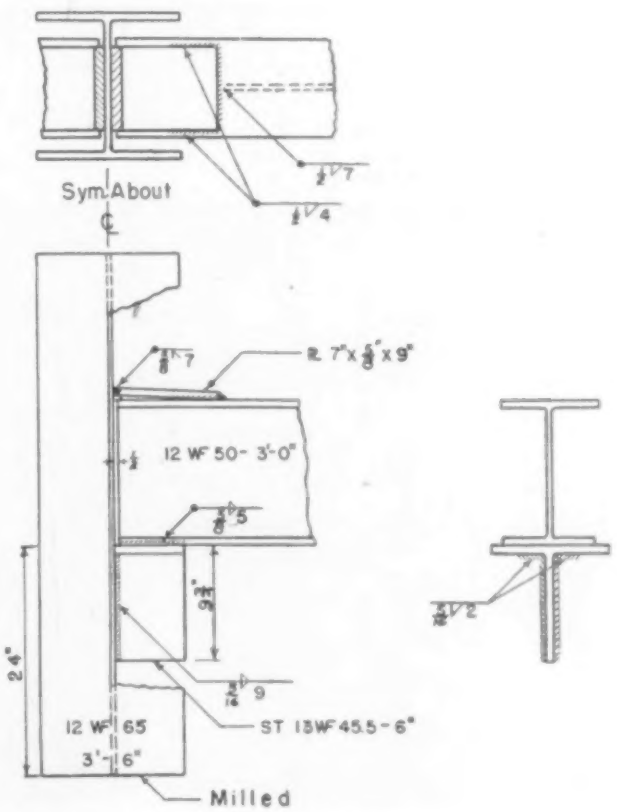


Fig. 36—Test 2

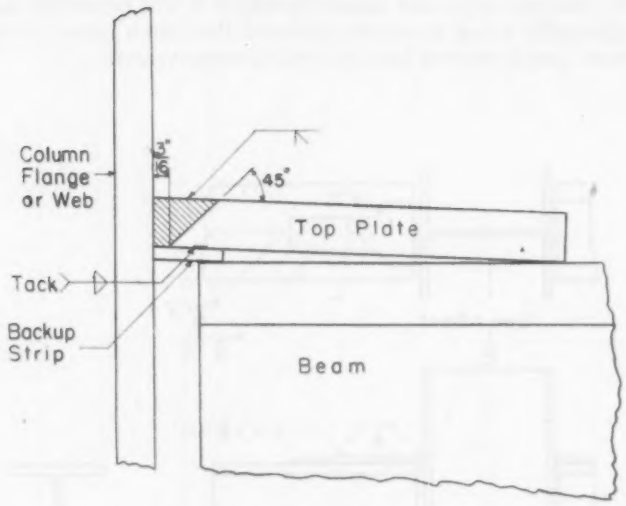


Fig. 37—Butt Weld Detail

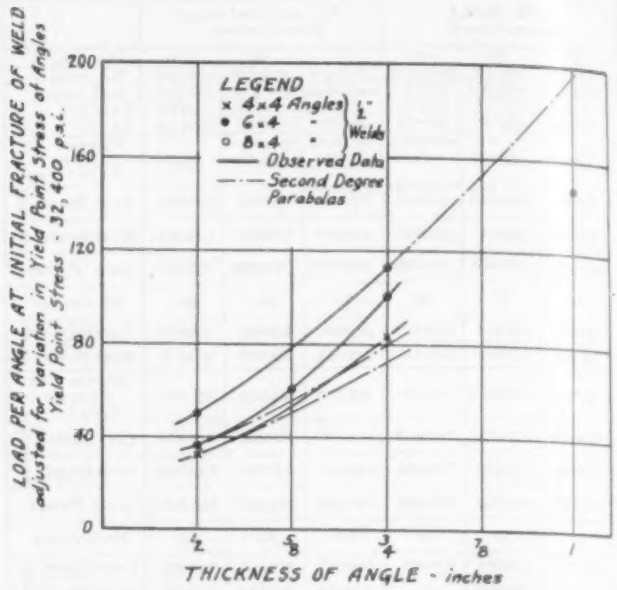


Fig. 39—Relation Between Thickness of Angles and Strength of Weld

Design of Stiffened Seats

The design of the stiffened seat is indicated on Fig. 40. The method is in agreement with that proposed by Priest[17, 18] in the assumption of stress distribution, location of neutral axis, etc., but the lever arm used in designing the welds is determined from Fig. 1 instead of by assuming a constant arm as suggested by Priest. The report on Structural Brackets[6] confirms the design method for the weld stress, but the method of loading the specimens does not permit of any conclusions as to the lever arm to be used. Jensen[6] recommended that the stiffener be designed for the combined stress

$$f = \frac{R}{A} + \frac{M}{S}$$

If this total stress be limited to 20,000 psi. and the lever arm is arbitrarily assumed as 0.8 the seat projection, the stiffener will be much too stiff. Since the load is applied to the seat through the web of the beam and is transmitted to the support through the stiffener web, it should be obvious that if the length of bearing has been selected so that the load is properly distributed, the thickness of the stiffener need be little greater than the thickness of

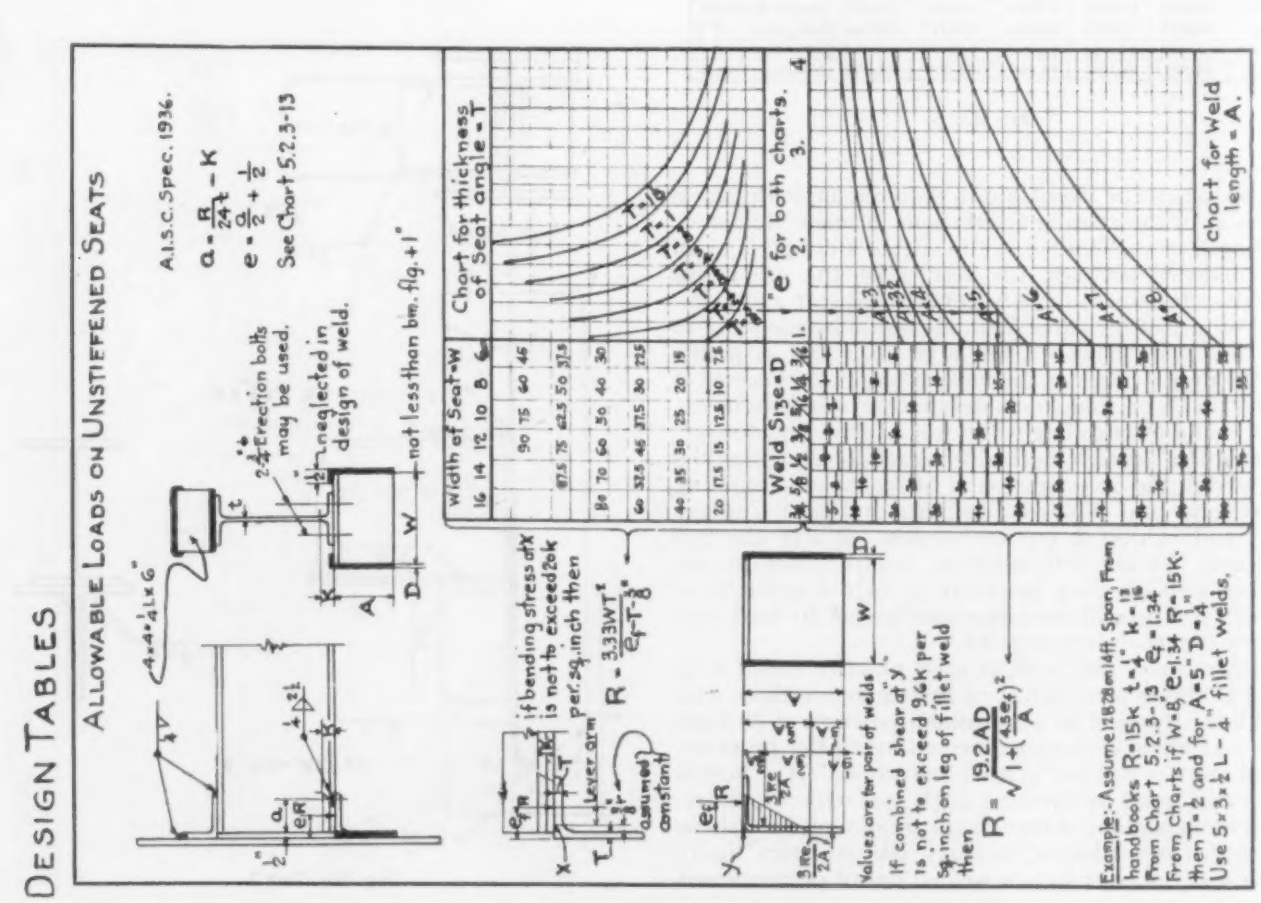

DESIGN TABLES
ALLOWABLE LOADS ON UNSTIFFENED SEATS
A.I.S.C. Spec. 1936.
a = R/2.4t − K
e = d/2 + 1/2
See Chart 5.2.3-13
2-¾ Erection bolts may be used.
½ neglected in design of weld.
not less than bm. flg. +1"
Chart for thickness of Seat angle = T
Width of Seat = W
Weld Size = D
"e" for both charts.
Chart for Weld length = A.
T=½
T=⅝
T=¾
T=⅞
T=1
T=1¼
A=3
A=4
A=5
A=6
A=7
A=8
If bending stress at X is not to exceed 20k per sq. inch then
R = 3.33WT²/(e−T−⅜)
Lever arm
assumed constant
If combined shear at Y is not to exceed 9.6K per sq. inch on leg of fillet weld then
R = 19.2AD/√(1+(4.5e/A)²)
Values are for pair of welds
Example:- Assume 12 B 28 on 14ft. Span. From handbooks R=15K t=½" k=1⅜
From Chart 5.2.3-13 e=1.34
From Charts if W=8, e=1.34 R=15K.
then T=½ and for A=5" D=¼"
Use 5×3½×½ L – ¼" fillet welds.

Fig. 38

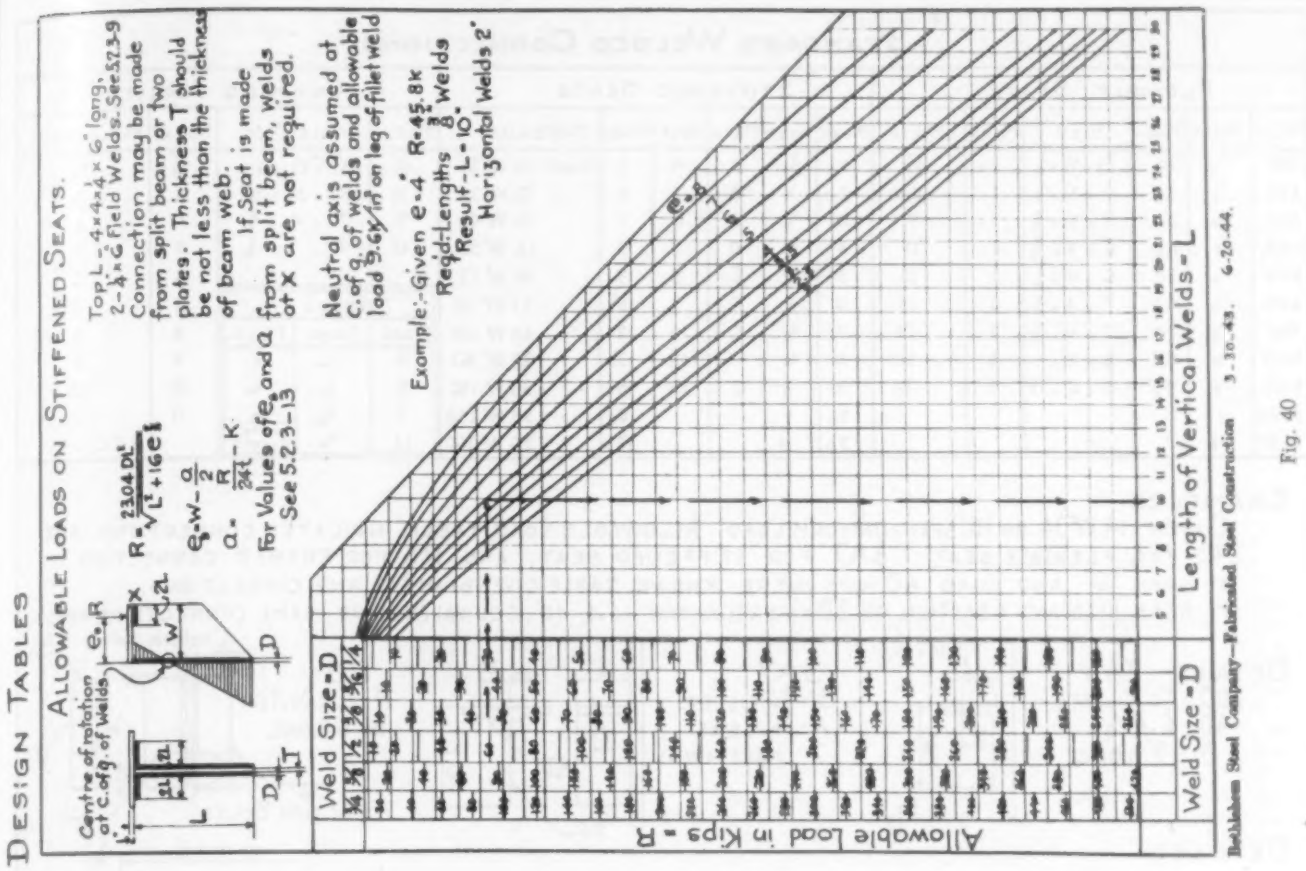

DESIGN TABLES
ALLOWABLE LOADS ON STIFFENED SEATS.
Top L - 4"x4"x 6" long, 2-4"ø Field Welds. See 5.23-9
Connection may be made from split beam or two plates. Thickness T should be not less than the thickness of beam web.
If Seat is made from split beam, Welds at X are not required.
For Values of e and a See 5.2.3-13
Neutral axis assumed at C. of g. of welds and allowable load 9.6k/in on leg of fillet weld
Example:-Given e=4" R=45.8k
Reqd-Lengths 8" Welds
Result-L-10"
Horizontal Welds 2"
Centre of rotation at C. of g. of Welds
Weld Size-D
Allowable Load in Kips - R
Length of Vertical Welds - L
Bethlehem Steel Company—Fabricated Steel Construction 3-30-43. 6-20-44.

Fig. 40

the beam web. Too wide a bearing or too rigid a stiffener tends to concentrate the load over the outer edge of the seat, resulting in a greater moment in the stiffener and higher stress intensity in the beam web at this point. Jensen[6] also recommends that the horizontal weld be placed on top of the seat rather than under the seat as suggested by Priest.[17, 18] While there are several advantages in placing the weld on top it is more practical from a fabricating and erecting viewpoint to avoid any weld on top of the seat.

While the 20% ratio of horizontal to vertical weld suggested by Priest results in a well-proportioned detail, the use of other ratios up to say 50% is desirable at times and the same design method is applicable. The use of one ratio simplifies the preparation of a design chart and is desirable in setting up standards, but special cases can easily be designed if charts for 20, 30, 40 and 50% are prepared. By interpolation the values of continuous welds on standard structural tees may readily be determined.

Recommended Design Methods

Summarizing the matters presented thus far, design assumptions and procedures have been proposed for framing angles, flexible and stiffened seats, top angles, top plates for flexible, semirigid, and rigid construction. It is the author's contention that the design methods of this paper and those of Fish, Priest, Johnston and others are in fair enough agreement with each other and with the Lehigh Research Reports to justify the official adoption of recommended design methods for all of these items, by the AMERICAN WELDING SOCIETY and the American Institute of Steel Construction.

Recommended Standard Connections

In addition to this standardizing of methods, it is further proposed that for the more customary construction type, viz., simple-span or flexible construction, actual details, symbols and capacities for top angles, framing angles, flexible seats and stiffened seats, be now standardized and published by the American Institute of Steel Construction.

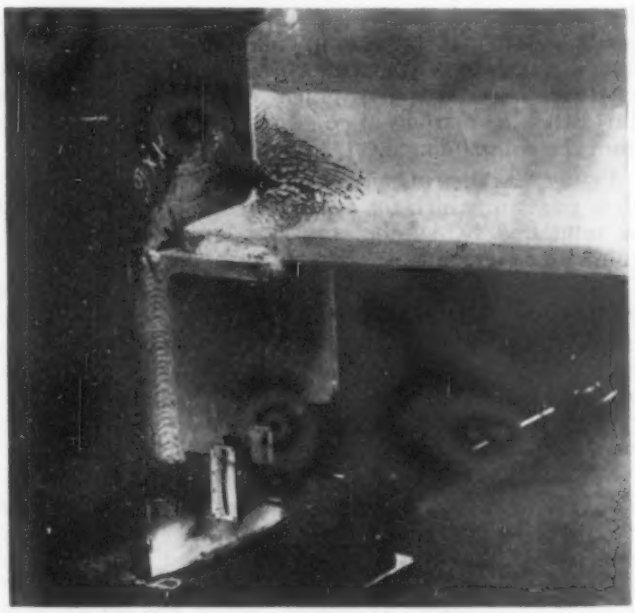


Fig. 41

STANDARD WELDED CONNECTIONS

FLEXIBLE SEATS

MARK	WELD	MARK	SIZE	MARK	LENGTH
100	3/16	10	3½ × 3½ × 3/8	1	4½
200	1/4	20	4 × 3½ × ½	2	6½
300	5/16	30	5 × 3½ × 5/8	3	9
400	3/8	40	6 × 4 × 5/8	4	11
500	7/16	50	6 × 4 × ¾	5	13
600	½	60	7 × 4 × ¾	6	15
700	5/8	70	7 × 4 × 7/8	7	17
800	¾	80	8 × 4 × 1	8	20
900	7/8	90	8 × 6 × 1⅛	9	24
9a00	1				
9b00	1⅛				

STIFFENED SEATS

MARK	WELD	MARK	SEAT	MARK	MATERIAL
1	3/16	A	4	5	HALF 10 WF 21
2	1/4	B	5	6	" 12 WF 32
3	5/16	C	6	7	" 14 WF 43
4	3/8	D	7	8	" 16 WF 58
5	7/16	E	8	9	" 18 WF 77
6	½	F	9	10½	" 21 WF 112
7	5/8	G	10	12	" 24 WF 150
8	¾	H	12	13½	" 27 WF 163
9	7/8	J	15	15	" 30 WF 190
9a	1			16½	" 33 WF 220
9b	1⅛			18	" 36 WF 260

FRAMING ANGLES

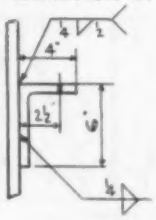
MARK	ANGLE SIZE	MARK	ANGLE LENGTH
R	3½ × 2½ × ¼	2½	2½
S	5 × 3½ × 5/16	3	3
T	7 × 4 × 3/8	4	4
U	4 × 3 × 3/8	5	5
		6	6
		7	7
		8	8
		9	9
		10	10
		11	11
			ETC.

WELDS		
MARK	SHOP	FIELD
R	3/16	¼
S	¼	5/16
T	5/16	3/8
U	3/16	BOLTS RIVETS

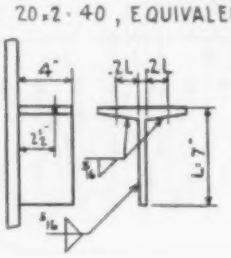
EXAMPLES:

GIVEN 14 WF34 ON 16' SPAN - UNIFORM LOAD. ALLOWABLE LOAD TABLE INDICATES CONNECTIONS ARE 243 FOR FLEXIBLE SEAT, 3A7 FOR STIFFENED SEAT, AND R8 FOR FRAMED CONNECTION. IF SPAN 16' AND LOAD 40 KIPS WERE KNOWN, TABLE GIVES BEAM SIZE AND CONNECTIONS. IF BEAM SIZE AND REACTION OF 20 KIPS ARE KNOWN 20 × 2 = 40, EQUIVALENT LOAD, SAME CONNECTIONS APPLY.

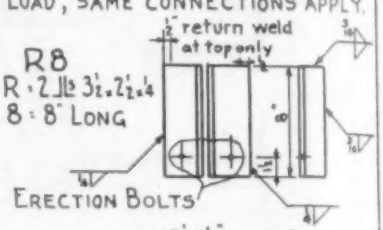
DETAILS 243
200 · 4" FILLETS
40 · 6 · 4 · 5/8 L
3 · 9" LONG



3A7
3 · 5/16" FILLETS
A · 4" SEAT
7 · HALF 14 WF 43



R8
R · 2 L's 3½ × 2½ × ¼
8 · 8" LONG



DETAILED

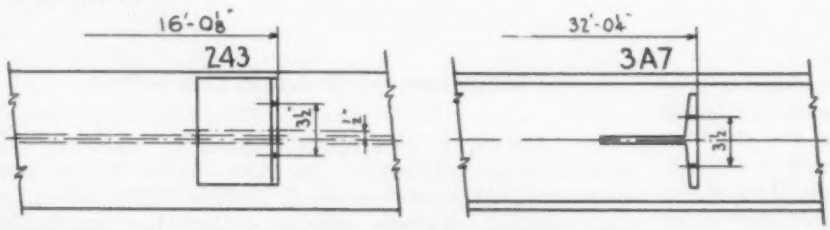


Fig. 42

Figure 42 is offered as part of such a standard. It shows the dimensions of a full range of framing angles, of flexible seats and of stiffened seats. It gives the key to a symbol system to be used in calling for these details on shop drawings and illustrates how the details should be located and their marks given, on such drawings. It illustrates the method of choosing standard connections from the companion sheet, Fig. 43.

Figure 43 illustrates a typical one of a series of handbook pages in which for every rolled beam, there would be tabulated by symbol the standard connections required to develop its capacity on any given span.

Neither figure shows the standard top angle. This would be, for all seated beams, 4 x 4 x 1/4 x 0 ft. 6 in. (symbol C6) for all beams with flanges wider than 4 in., and 4 x 4 x 1/4 x 0 ft. 4 in. (symbol C4) for all other beams. Welds for both standard top angles would be continuous 1/4-in. fillets on their two toes, without returns.

Structural Engineers will recognize from these proposed standards that a high degree of standardization is possible; that while the same connection cannot apply over a wide range of beams of the same depth, it can apply over limited ranges in various depths. While not as readily memorized as riveted details, the existence of safe load tables such as indicated in Fig. 43 makes the selection of these standard details a very simple matter.

It is not proposed as yet to similarly standardize the details for rigid or semirigid framing; only, as above indicated, the methods of design for such details.

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ALLOWABLE LOAD TABLE MODIFIED FOR WELDED DETAILS.

Nominal Depth and Width - Weight per Foot.

14 × 6¾

Span in Feet	42 Detail	42 Load	38 Detail	38 Load	34 Detail	34 Load	30 Detail	30 Load
6		126		116		104		98
7		116		104		92		93
8		101		91		81		80
9		90		81		72		70
10		81		73		65		62
11		74		66		59		56
12		67		61		54		51
13		62		56		50		46
14		58		52		46		43
15		54		49		43		40
16		51		46		40		37
17		48		43		38		35
18		45		40		36		33
19		43		38		34		31
20		41		36		32		29
21		39		35		31		28
22		37		33		29		27
23		35		32		28		25
24		34		30		27		24
25		32		29		26		23
26		31		28		25		22
27		30		27		24		21
28		29		26		23		21
29		28		25		22		19.9
30		27		24		22		19.2
								18.6

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Also in the bibliographies of all these papers are many other references applicable to the subject.

Fig. 43 (Left)—Explanatory Notes

Loads Are in Kips (one thousand pounds units) and those above the solid lines in the load column produce excessive shear in the beam web, those above the long dash lines exceed the value of standard riveted "A" connections, those above the short dash lines exceed the values of standard riveted "B" connections, while those below the dotted lines produce excessive deflections for plastered ceilings. Loads above the dash lines require "H," "HH" or special riveted details, while loads above the tabular welded details will require special welded details.

The design of the welded details is based on a reaction equal to one-half the uniform load; hence, to use the tables for any known reaction, multiply the reaction by two and select the corresponding detail for that beam.

As a practical design consideration no smaller detail is indicated than that required at the load which produces a deflection equal to $^{1}/_{360}$ of the span.

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Fundamentals of Heavy Cutting*

By G. L. Walker† and H. G. Hughey†

Part I—Records and Data

Introduction

THE cutting of heavy sections of steel by the oxygen process, though not a new accomplishment, has been subjected to many uncertainties which have hampered its fullest application. Yet, in spite of these uncertainties, wartime needs have provided the stimulus for attempting applications which ordinarily would have been avoided, and have permitted the development of knowledge which has assisted in placing the process on a substantial basis.

In the past, procedures have too often been established about individual experiences based upon specific applications which, in turn, have suggested that certain limitations existed. To retain its place and to enable expansion into new fields, heavy cutting must become better appreciated fundamentally by those responsible for its successful execution.

The mere listing of accumulated data, while of interest, has not in itself proved sufficient to explain the effect of the many factors involved. Of more importance is the establishment of methods of analysis which disclose relationships and trends that can be translated into usable information. With this in mind, a study of the problem of cutting heavy sections was undertaken. A rather broad field was explored in a generalized manner, anticipating that an extensive analysis would disclose those factors which later could be studied in detail most profitably. It was not intended that this information would be just another theoretical dissertation, but rather would be a means for bringing out information of importance in the design of equipment and in the conditions of use.

The term "heavy" is somewhat abstract and is governed by individual circumstance, but for the purpose of this study, material of 12 in. and greater thickness was so classed. The groundwork was formed about 12-in. material for practical reasons, but activity extended beyond this thickness.

Available Records

Records of activity were examined, but much of the information lacked references to the standards used or lacked details which seemed necessary for the interpretation undertaken. The outstanding characteristics seemed to be the lack of agreement of conditions of operation used to obtain similar results, and the lack of repetitive and comparable results from apparently similar conditions of operation. Extrapolation of data for thinner sections provided helpful information, but had to be used with discretion.

Some of the records examined are listed in Tables 1 to 3. Tables 1 and 2 are results obtained from a study conducted a number of years ago with hand torches, machine conveyed, and are restricted to 12-in. material. The pressures listed are those at the regulator with about 25 ft. of 1/4-in. hose being used. The standards of cut called for commercially acceptable products and permitted variation, thus making close comparison impractical. The information so listed represents commercial recommendations of the time. Table 3 is a record of typical practices for various thicknesses, arranged chronologically. It will be noted that certain details of information are lacking, again making close comparison difficult.

A further record is to be found in the collection of data by the Welding Research Committee of the Engineering Foundation, and published in Vol. V, No. 5, May 1940 *Welding Research Supplement*.

General Considerations

In the establishment of bases for study and for the collection of data, certain factors were of obvious importance. These included the pressures, flows, tip sizes, speeds, details of cut, details of apparatus and type of material. Other factors became evident during the study, one of which can be termed as controllability, a qualitative measure rather than quantitative.

To establish some suitable standard for the comparison of the cuts, the measurement of the uncut corner was used, employing the product of the height and the base dimensions as a value. Drag lines could not be followed with certainty in all case. Much attention was

Table 1

EXAMPLES OF 12" CUTTING-HAND TORCHES-MACHINE CONVEYED-ACETYLENE

TORCH	CUTTING ORIFICE DIAMETER — INS	OXYGEN PRESS PSI	OXYGEN *FLOW-CFH	SPEED IN/MIN	PREHEAT **FLOW-CFH
1	.1285	100	730	3.9	44
2	.098	165	1050	2.8	43
3	.081	175	1080	2.9	80
4	.1065	165	1185	4.0	90
5	.1200	130	880	4.4	49
6	.1065	120	885	3.6	69
7	.096	NO CUT			25
8	.1200	120	1015	3.1	123
9	.089	148	840	2.5	46
10	.0995	150	985	3.6	40
11	.1405	120	920	3.7	73
12	.110	120	805	3.7	73
13	.157	130	1235	2.8	70
14	.1285	100	822	4.5	102
15	.098	100	624	3.7	105
16	.1285	83	648	3.8	64
17	.1065	160	1160	3.5	79

*— TOTAL FLOW—INCLUDES PREHEATING OXYGEN.

**— ACETYLENE ONLY

* To be presented at the Twenty-Fifth Annual Meeting, A.W.S., Cleveland, Ohio, Oct. 16 to 19, 1944

† Research Engineers, Apparatus Research and Development Dept., Air Reduction Sales Co.

Table 2—Examples of 12-In. Cutting—Hand Torches—Machine Conveyed—Hydrogen

TORCH	CUTTING ORIFICE DIAMETER—IN	OXYGEN PRESS-PSI	OXYGEN *FLOW-CFH	SPEED IN/MIN
1	.1285	170	1315	34
2	.1065	165	1100	4.2
3	.1200	130	1240	4.7
4	.1065	120	830	3.6
5	.0935	140	800	2.9
6	.0960	165	990	3.5
7	.0935	140	584	2.7
8	.1160	150	1170	3.5
9	.1440	120	980	3.7
10	.1110	120	800	3.7
11	.157	135	1220	3.7
12	.1285	100	844	4.3
13	.082	105	755	3.7
14	.1285	75	624	4.2
15	.1065	180	1080	3.1

*-TOTAL FLOW-INCLUDES PREHEAT OXYGEN
PREHEAT FLOWS NOT OBTAINED

Table 3—Examples of Cutting Various Thicknesses—Machine Cutting Torches

NO.	DATE	THICKNESS INS	MATERIAL	CUTT.ORIF. DIAM.INS.	SPEED IN/MIN	REGULATOR PRESS PSI
1	1919	14-16	.25/.30C	—	2.5/3.0	—
2	1919	18-24	.25/.30C	—	2.5/3.0	—
3	1924	17-23	.30/.35C	.1495	2.0/2.5	100/125
4	1927	28	.20/.27C	—	3.5	100/125
5	1929	26	L.C.	.180	2	150
6	1930	32	.25/.30	.180	1.2	145
7	—	25	.40	.161	2	100/145
8	1938	25	—	.172	2.8	120
9	1939	24-26	ALLOY	.180	1.8	175
10	1940	18	.60C	.180	3	120
11	1941	16	ALLOY	.180	4	120
12	1942	25	ALLOY	.180	3	145
13	1942	20-22	ALLOY	.180	2.5/3	150
14	1943	34	ALLOY	.332	3	135
15	1944	36	20C	.375	3	135

*—PRESSURE AT TORCH ENTRY

given to the measurement and requirements of flow of the cutting oxygen on the assumption that this was a major controlling factor.

Equipment was restricted to commercially available items or to those items which could become commercially available, reserving the use of specially designed equipment for the more detailed investigations anticipated.

Calibration of Equipment

All equipment was calibrated for pressure and flow conditions, the pressure measurement being taken at the entry to the torch to avoid the effect of pressure drops through the hoses, controls and other devices. Not only did this calibration embody the tips, but it also included the torches without tips, thereby establishing a general picture of the range of flow which was possible for each torch. These pressure and flow relations were recorded in a manner shown in Plates I, II and III which cover three of the principal torches under study. Utilization of logarithmic relations proved particularly suitable for covering the wide range of values involved. The relations shown in Plate I are those of a torch which has long been in general use and is of the 3-hose type. An orifice size of 0.180 in. diameter is the limit due to dimensional restrictions in tip design. The torch covered by Plate II is somewhat larger than that covered by Plate I, is of the 3-hose type, and has for a limit a tip orifice of 0.332 in. diameter. The torch covered by Plate II is of recent design and is of the 3-hose type, and is specifically arranged for large capacity. Its orifice limit is about $^1/_2$ in.

From the flow data obtained, it was evident that a zone could be established wherein the torch became a restrictive factor to flow rather than the tips. This was obtained for each torch from a constant pressure plot of the flows and orifice sizes, extending to the flow of the torch itself. A composite graph of this relationship for 7 torches is shown in Plate IV. Along the straight section, the tip size alone controls the flow and pressure relationship. At the point of curvature, the torch becomes a restrictive factor, increasing in effect until it controls the conditions entirely as shown by the vertical section. Thus, for any specific torch, the limit of practical tip size purely from the oxygen flow standpoint can be determined. For example, for torches 1, 2 and 3, at a torch entry pressure of 100 psi., the maximum flow for any of the torches alone is in the neighborhood of 1500 cfh., as shown by the vertical lines *1*, *2* and *3*, whereas for torch 7, the limit is about 30,000 cfh., as shown by the vertical line *7*. The practical significance of such basic information lies in the ability to compare and to select equipment with a known flow range and of adequate capacity.

Tests and Data

Many experimental test runs were made under diverse conditions so arranged as to develop a definite family of relationships. The listing of the individual results is too extensive to be included in this article in its entirety, thus the principal relations for 12-in. material are presented in

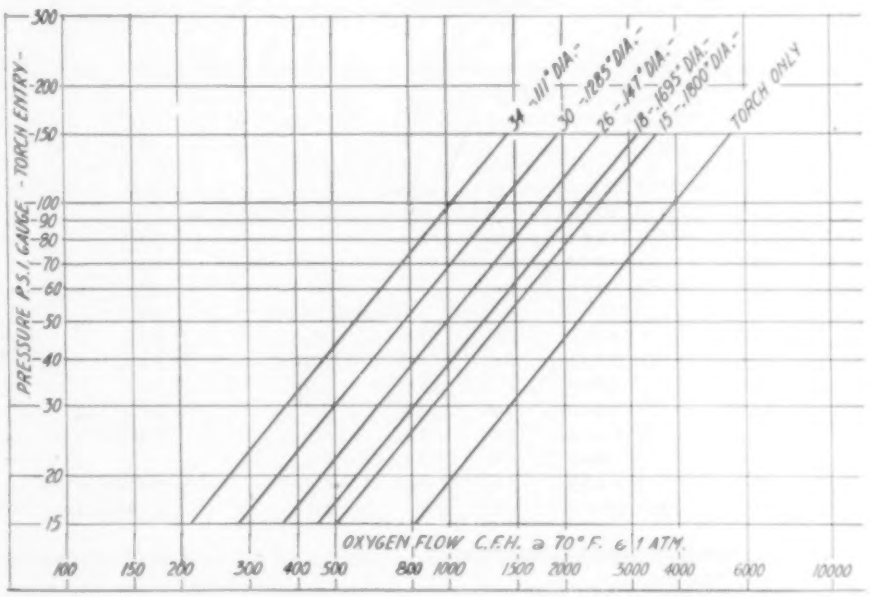


Plate I—Flow Relations Torch No. 5; 3-Hose Torch of Conventional Type in Wide Use

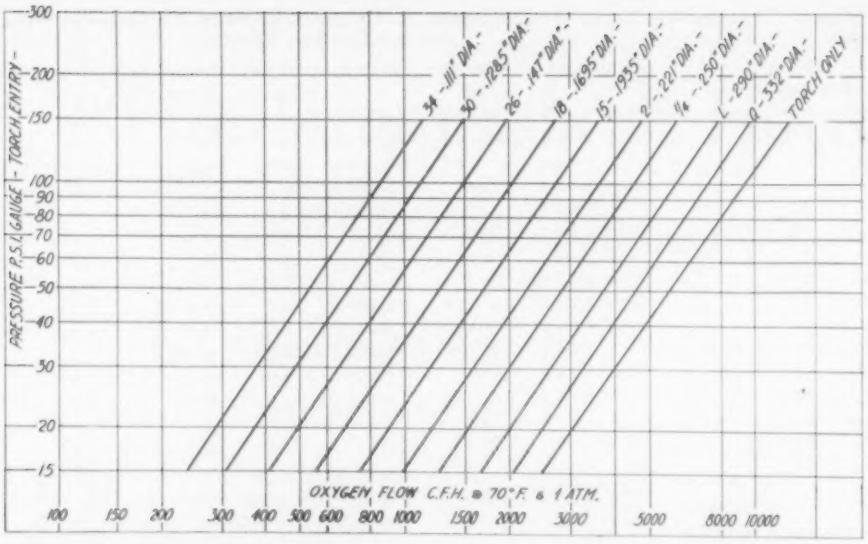

PRESSURE P.S.I. GAUGE - TORCH ENTRY
OXYGEN FLOW C.F.H. @ 70°F. & 1 ATM.
34 - .111" DIA.
30 - .1285" DIA.
26 - .147" DIA.
18 - .1695" DIA.
15 - .1935" DIA.
2 - .221" DIA.
1/4 - .250" DIA.
L - .290" DIA.
0 - .332" DIA.
TORCH ONLY

Plate II—Flow-Relations Torch No. 6; New Type 3-Hose Torch of Intermediate Size

graphical form, Plates V and VI. These relations cover the flow, pressure, speed and uncut corner product. Plate V covers the relations for three sizes of tips of a type in common use. Plate VI covers the relations for three additional tips with larger orifices than those shown in Plate V and with a slightly different preheat disposition.

Data for greater thicknesses were obtained after considerable study of 12-in. operations and were limited to a narrower range of conditions which appeared to offer the most promise. Thus, the establishment of graphs was not feasible and the results are listed in Tables 4 to 6. Table 4 covers 15-in. material, cut under several conditions. Table 5 covers 24-in. material cut under several conditions and discloses drop cuts in two instances. The first condition listed is one which has often been used in practice before present high-capacity equipment was available. Table 6 covers 30-, 34- and 36-in. material. The conditions are not broad enough to be conclusive, but do show trends.

Part II—Analysis and Discussion

Analysis of Data

A number of methods of analyses have been used to bring out the most pertinent relationships in the presentation of such data, but the rather wide range covered in this case suggested the need for a somewhat different form than was common. The graphical relations portrayed in Plates V and VI suggested certain common relationships between the various tips, but did not seem composite enough for the immediate purpose. Since the preponderance of data related to 12-in. material, comparisons were

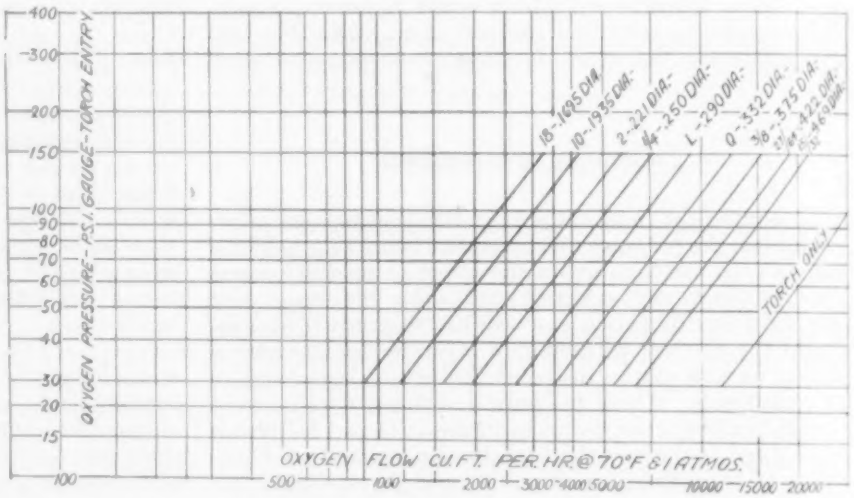

OXYGEN PRESSURE - P.S.I. GAUGE - TORCH ENTRY
OXYGEN FLOW CU.FT. PER HR. @ 70°F & 1 ATMOS.
18 - .1695 DIA.
10 - .1935 DIA.
2 - .221 DIA.
1/4 - .250 DIA.
L - .290 DIA.
0 - .332 DIA.
TORCH ONLY

Plate III—Flow-Relations Torch No. 7; New Type 3-Hose Torch, Heavy Duty

Table 4

TEST RESULTS—15 IN. MATERIAL SAE 1025

CUTT. ORIF. DIA. INS.	FLOW C.F.H.	PRESS. PSI	SPEED IN./MIN.	CORNER B X H
.1695	900	34	3.0	12
.1935	1150	33	2.9	6
.221	1250	27	3.1	6.5
.221	1350	30	3.1	4
.221	2400	60	3.1	FAILED TO CUT
.250	1300	25	3.0	5.5
.250	1530	30	3.0	3.0
.290	1650	25	3.0	6.5
.290	1950	30	3.5	3.5
.332	1850	25	3.5	8
.332	1950	29	3.9	6
421	2900	15	4.5	-0-
421	2900	15	5	5.5

ALL SURFACES SMOOTH AND STRAIGHT

PREHEAT FUEL—ACETYLENE

Table 5

TEST RESULTS—24 IN. MATERIAL SAE 1025

CUTT. ORIF. DIA. INS.	FLOW C.F.H.	PRESS. PSI	SPEED IN./MIN.	CORNER B X H	SURFACE
.180	2700	125	2.2	2.7	SMOOTH-STRAIGHT
.221	2400	60	2.9	4.5	FAIR—ROUGH-E
.332	2200	30	2.0	1.6	SMOOTH-STRAIGHT
.332	2200	30	2.2	9	SMOOTH-STRAIGHT
.332	1600	21	3.1	7.8	SMOOTH-STRAIGHT
✲ .332	2800	40	3.5	4	SMOOTH-STRAIGHT
✲ .332	2800	40	3.5	0	SMOOTH-STRAIGHT
✲ ✲ .332	3000	25	2.7	0	SMOOTH-STRAIGHT

PREHEAT FUEL—ACETYLENE

✲ PREHEAT FLOW GREATER AND FLAME DISPOSITION MORE ENCOMPASSING THAN OTHER RUNS.

✲ ✲ PREHEAT FLOW ABOUT 350 C.F.H.

Table 6

TEST RESULTS—30 IN. MATERIAL

CUTTING ORIFICE DIA. INS.	FLOW C.F.H.	PRESS. P.S.I.	SPEED IN/MIN.	CORNER B X H	PREHEAT
.332	3200	35	2.0	8	300 C.F.H.
.332	2600	38	2.3	8	390 C.F.H.
TEST RESULTS 34 IN. MATERIAL					
.375	6000	40	2.8	27	PROPANE
.332	3740	52	2.7	112	ACETYLENE
.332	3740	52	2.7	70	*PHT. ACET.
.332	5300	80	2.6	16	ACETYLENE
.421	5100	30	2.7	24	PROPANE
.332	3800	30	3.1	36	ACETYLENE
.332	3800	30	3.1	24	* PHT. ACET.

* PREHEAT INCREASED OVER EACH PREVIOUS RUN.

TEST RESULTS 36 IN. MATERIAL					
.375	4000	30	3.0	27	ACETYLENE
.375	3600	27	2.8	60	ACETYLENE
.375	4500	36	3.0	55	ACETYLENE
.375	4500	36	2.5	55	ACETYLENE

ALL SURFACES SMOOTH AND STRAIGHT.

ing 2 at line *2–2* and continuing until the cut cannot be maintained.

At the left, within the circle *A* is the region wherein most past conditions of operation occur, and is characterized by low flow and low speeds as well as limited drop-cut conditions. In this region, slight variations in speed affect the corner conditions to a large degree, and likewise flow variations have serious effect. Within this circle are blocked off the recommendations shown in the *Welding Handbook*. The effect on the resultant corner value from operating conditions which vary to only a small degree provides some clue to the diverse results often reported, particularly when the operating conditions are not closely maintained.

In the center section, circle *B* contains conditions which were found to give rise to maximum speed and good control. Drop cuts were readily obtained and considerable latitude in variations was possible without seriously affecting the results. For instance, with a speed of 4 in. per minute and a flow of 1400 cfh., a variation of as much as 25% in the speed and 10% in the flow did not seriously change the results.

To the right is another circle *C* which designates conditions of extreme flow. It is to be noted that as the flow is increased to excess, the possible speed of operation is reduced, thus providing another clue to the diverse results reported. In this region, there also exists a

made in this field and applied to other thicknesses later. It was noted that all tips produced strikingly similar results for the same general order of flows, hence suggested that a comparison should be made on the basis of oxygen consumption, speeds and uncut corners, merging the tip sizes to form a composite relationship. From these graphs, Plates V and VI, the composite interrelation was developed as shown in Plate VII and includes certain qualitative interpretations and references to conditions of general use.

Line *1–1* in Plate VII approximately locates the condition of uncut corner with a product of 1. Below this line, the corner decreases, until drop cuts are effected. Below the drop-cut zone, there appears to be a zone wherein the results may be quite erratic due to extremely slow speeds, characterized by poor surfaces, uncut corners and poor control. In the other direction, greater uncut corners become evident be-

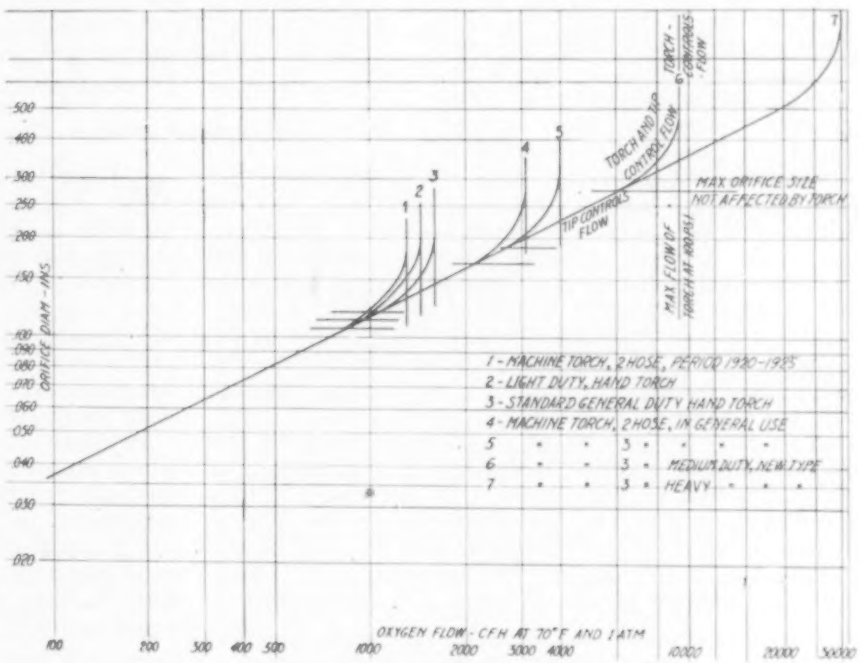
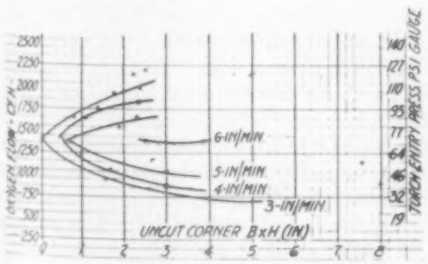
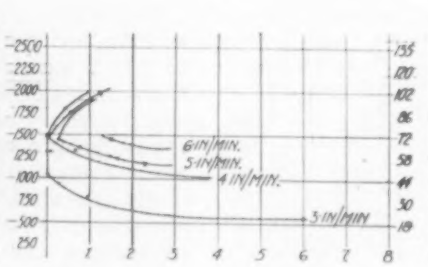

ORIFICE DIAM - INS
OXYGEN FLOW - C.F.H. AT 70°F AND 1 ATM
TORCH AND TIP CONTROL FLOW
TIP CONTROLS FLOW
MAX FLOW OF TORCH AT 400 PSI
MAX ORIFICE SIZE NOT AFFECTED BY TORCH
1 - MACHINE TORCH, 2 HOSE, PERIOD 1930-1935
2 - LIGHT DUTY, HAND TORCH
3 - STANDARD GENERAL DUTY HAND TORCH
4 - MACHINE TORCH, 2 HOSE, IN GENERAL USE
5 " " 3 " " " "
6 " " 3 " MEDIUM DUTY, NEW TYPE
7 " " 3 " HEAVY " " "

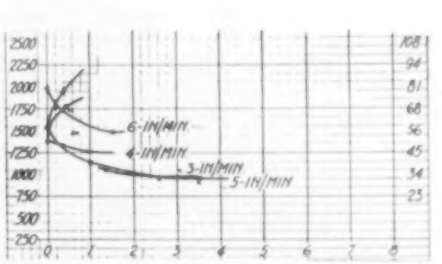
Plate IV—Limiting Conditions Controlling Flows of Various Torches and Tips at Constant Torch Entry Pressure of 100 Psi.



Tip Orifice Diam.—0.1495 In. 4-Preheat Acetylene

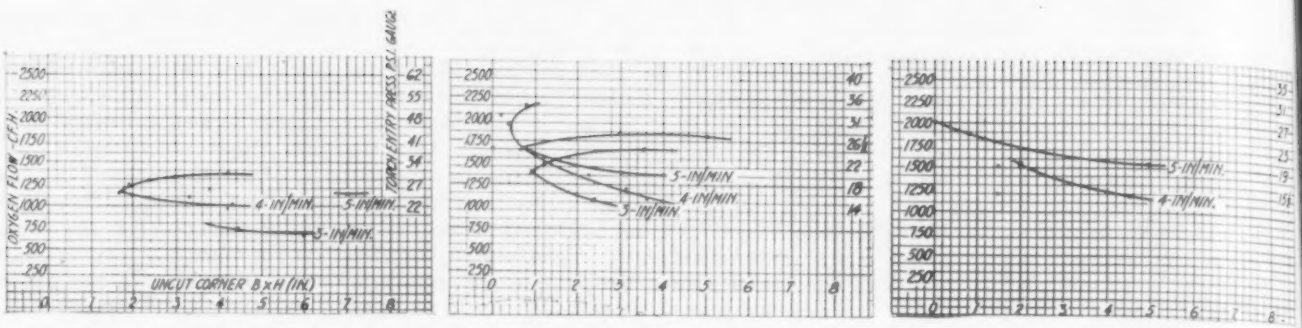


Tip Orifice Diam.—0.161 In. 4-Preheat Acetylene



Tip Orifice Diam.—0.180 In. 4-Preheat Acetylene

Plate V—Interrelation of Factors for 12-In. Material S.A.E. 1025 Preheat—Fuel Acetylene



Tip Orifice Diam.—0.221 In. 4-Preheat Acetylene

Tip Orifice Diam.—0.290 In. 4-Preheat Acetylene

Tip Orifice Diam.—0.332 In. 4-Preheat Acetylene

Plate VI—Interrelation of Factors for 12-In. Material S.A.E. 1025 Preheat—Fuel Acetylene

marked deterioration in the surface quality and control of operations.

Since a basic consideration is that of the oxygen flow used, some indication of tip size is evident. Small tips at high pressures or large tips at low pressures can be examined in the light of the flow determinations. For example, a tip with a No. 32 drill (0.116 in.), at 150 psi., or one with a No. 15 drill (0.180 in.) at 50 psi., or one of 0.260 in. at 20 psi. will pass 1400 cfh. thus indicating the order of large and small as the terms apply to this particular value. The general conception that tips of small size are most economical is not substantiated in this case unless the terms are definitized. In general, it can be said that any tip which will not pass the required amount of oxygen within the limits of available pressure is too small and any tip which will pass the same amount at extremely low pressures, say below 15 psi., is too large. A determination of the efficiency of operation can also be developed. For a constant uncut corner condition, for example, that having a product of 1, the oxygen consumption per lineal inch of travel is listed in Table 7. Note that for the very low speeds and flows, a relatively low unit consumption exists, increasing to a maximum at about $2\frac{1}{2}$ to 3 in. per minute, then decreasing until a speed of about 4 to 5 in. per minute is reached. For an increase in speed of 100%, that is, from $2\frac{1}{2}$ to 5 in. per minute, the oxygen demand increases only 70%. Similarly, as between speeds of 4 and 5 in. per minute, a speed increase of 25%, the oxygen demand increases only 17%. Thus, at the speeds which have been most extensively used in the past, the least efficiency of oxygen consumption has existed.

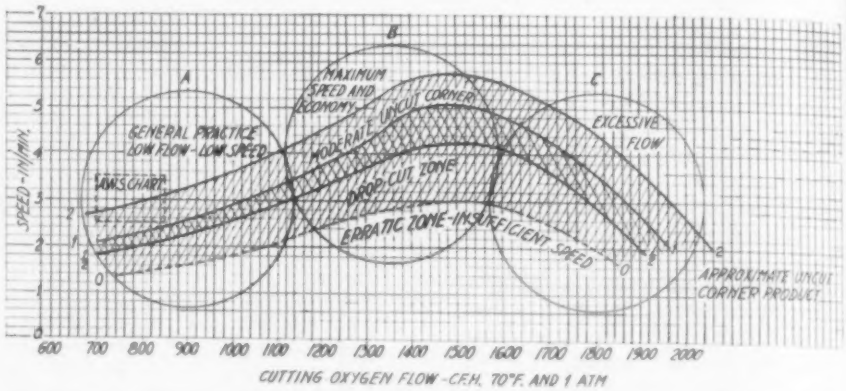


Plate VII—Operational Survey for Cutting 12-In. Steel S.A.E. 1025, Preheat—Acetylene

Increase of oxygen consumption beyond that which results in a maximum speed results in a lowering of attainable speeds and a marked decrease in efficiency. It must also be realized that at the higher speeds which display the greater efficiencies, the conditions are more desirable from the production standpoint.

In continuing the study of conditions beyond those which represent customary practice, it is evident that not only can the most desirable operating conditions be established, but also some understanding of the irregularity of reported results is to be gained. Other factors exist which do influence results to various degrees, and further study will serve to definitize the effects. The general trend of effects is apparent at present.

Table 7—Cutting Oxygen Requirement for 12-In. S.A.E. 1025 Steel
Uncut Corner Product, 1

OXYGEN FLOW C.F.H.	SPEED IN/MIN	OXYGEN PER LINEAL INCH C.F.H.
500	1.6	5.2
600	1.8	5.5
700	2.1	5.5
800	2.3	5.8
900	2.6	5.8
1000	2.9	5.7
1100	3.3	5.6
1200	3.8	5.3
1300	4.4	4.9
1400	5.0	4.7
1500	5.0	5.0
1600	4.8	5.6
1700	4.3	6.6
1800	3.6	8.3

Tip Pressure

Industry has been accustomed to speaking of pressures as those indicated at the regulator with little concern as to what occurs beyond this point. Such a condition has perhaps been the cause for the development of various theories which no doubt appear sound for specific conditions but which fail when extended to general practice. Pressures at the entry to the cutting orifice directly affect the stream characteristic, whereas those at some point removed, due to the effect of other variable restrictions are of only secondary value. For entry pressures under the critical, that is 27.8 psi., abs., the stream density remains virtually unchanged as the pressure varies while the velocity of the traveling stream increases as the pressure is increased. At the critical pres-

sure, the velocity is in the neighborhood of that of sound. Above this value, with added pressure, the velocity increases only a limited amount, the principal effect of the pressure being to increase the density of the gas within the stream. Thus above the critical pressure, the stream issues at approximately the acoustical velocity, but having definite internal pressure, it expands immediately upon leaving the orifice since this internal pressure no longer is confined by solid walls. The degree of expansion depends upon the internal pressure, and does affect the resultant conditions of cut.

If the expansion is small, turbulent conditions are not prominent and a maximum control of operations is displayed. On the other hand, if extreme expansion takes place, difficult control is evident and the results may be erratic. Some expansion appears desirable to insure a maximum stream velocity.

If we consider the expansion ratio as the relation between the diameters of the expanded stream and that of the stream confined within the walls of the orifice, and both traveling at the same velocity and unaffected by temperature, this ratio can be reduced to a simple value of $R = 0.036P$, wherein P is the absolute tip entry pressure. This applies to simple orifices wherein no specific shape has been applied to the entry or exit portion for the purpose of influencing the conditions of expansion. On this basis Table 8 has been prepared. This also assumes no appreciable temperature change due to either stream expansion or heating from the preheat flames.

It must be borne in mind that the expansions listed in Table 8 are primarily for comparative purposes, since in actual practice, temperatures and mechanical detail will alter the value in an indeterminate manner.

From the observations of the many cuts made, it was concluded that the range between 25 and 50 psi., resulted in the best general control and the most satisfactory results. Pressures outside of this range could be used, but posed increasing problems leading to generally unsatisfactory results unless specific attention was devoted to the details in evidence.

Flow Requirements

From the relation of the flows with respect to the results obtained for various thicknesses of materials, it was evident that some demand constant could be developed in terms of the thickness of material. For 12-in. material, flows between 1000 and 1500 cfh. appeared to be most desirable. In terms of thickness, this resolves to values of from 80 to 125 cfh. per inch of thickness. For the establishment of an intermediate value suited to initial set-up conditions and to convenient estimate, it is proposed that a value of 100 times the thickness in inches ($100T$) be used. The Welding Research Committee of the Engineering Foundation in their supplement of May 1940, Vol. V, No. 5, page 166, cites a similar relation by DeJessey wherein he estimated a value of about $88T$ for about 25-in. material.

In the investigation of thicknesses other than 12 in., the relationship of $100T$ was used with good result, this flow being supplied within a pressure range of 25 to 50 psi. For values above $100T$, drop cuts were obtained for 24-in. material and very nearly so for 36-in. material, all at speeds of about 3 in. per minute. The use of such definite relations proved of much value in being able to avoid "hit and miss" conditions and should be of similar value to the field.

Table 8—Expansion Ratios of Cutting Jets

GAUGE PRESSURE-PSI TIP ENTRY	EXP RATIO	GAUGE PRESSURE-PSI TIP ENTRY	EXP RATIO	GAUGE PRESSURE-PSI TIP ENTRY	EXP RATIO
13.1	1.0	45	1.47	100	2.04
15	1.03	50	1.53	110	2.13
20	1.12	55	1.59	120	2.20
25	1.20	60	1.64	130	2.28
30	1.27	70	1.75	140	2.36
35	1.34	80	1.85	150	2.44
40	1.41	90	1.95	160	2.52

Preheat

It perhaps has been noted that as yet, no mention of preheat has been made. This phase constitutes a study in itself, and if injected into the preceding analyses could confuse rather than clarify. In many cutting investigations, it appears that the preheat has been subordinated to a point wherein it is dismissed as of relatively little importance. In fact, statements have been made relative to cutting without preheat, implying that it is not necessary once the cut is started. No doubt such comments have grown from purely theoretical considerations of the chemical combination of oxygen and iron, and from observations made with thin clean steel under carefully controlled conditions. It is possible to shut off the preheat once a cut is started and to have the reaction continue but the action which results certainly cannot be classed as cutting in the accepted sense, since the pattern of performance is far different than exists with the preheat operating. Particularly with the heavier sections, the necessity for substantial preheat was evident and with the proper relation cuts were made which were not otherwise possible.

Measurement of preheat flows used to accomplish good cuts disclosed that for acetylene, flows of from 10 to 15% of the cutting oxygen were most satisfactory. The flows required on this basis have been in excess of the capacity of much equipment and thus suggest another reason for unsatisfactory results.

The effectiveness of the application of such volumes bears a direct relation to the manner in which it is applied. With the conventional disposition of the flames, excessive melting of the upper corner may exist, but if we are to limit ourselves to a preheat condition based upon a corner condition, we may find that other relations are so unbalanced that a cut cannot be made at all. Some control can be gained by operating the tip from 1 to 2 in. above the work and there is evidence that this spacing is very satisfactory. Particularly with heavy sections, a melted or rounded top corner is not generally objectionable if otherwise the cut is of high quality and can be made with certainty.

If we refer to the general relationships shown on Plate VII the effect of the preheat will be to change the location of the curves as indicated in Plate VIII. For example the base curve, 2, locates a flow valve A and a speed value D to produce a particular result.

If less preheat is used, the base curve, Plate VIII, may shift to 1, thus indicating the need for more oxygen by the amount AC or less speed by the amount DF to obtain the same results if they are at all possible. Similarly, with more preheat, the oxygen consumption may be less by AB or the speed may be more by the amount DE. However, it must not be expected that indefinite preheat increase will continuously better the results, for a maximum will be reached beyond which results will become inferior.

Perhaps the preheat can best be looked upon as a form

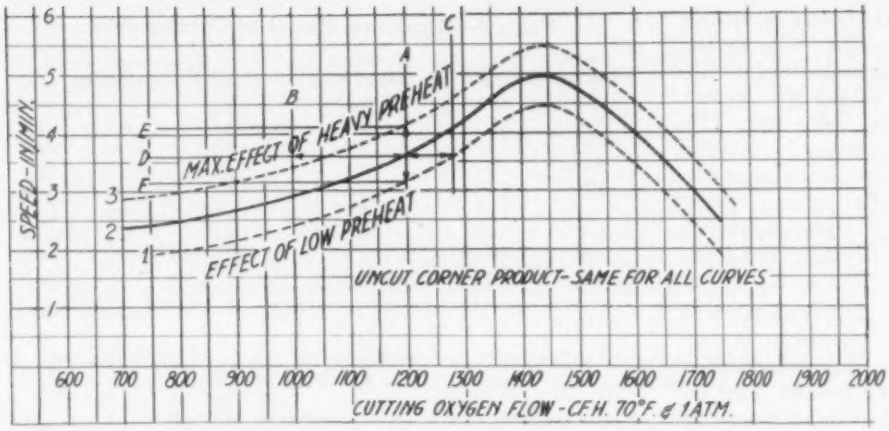


Plate VIII—Effect of Preheat on Location of Curve of Uncut Corner as Developed in Plate VII

of catalyst which controls the chemical process. Too little or too much is undesirable, but a specific amount establishes a balance of conditions which are conducive to the best performance.

Other Considerations

Other considerations can be cited which affect the outflow of the stream or which affect the balance of the reaction. These include such factors as chemical analysis of the steel, the surface conditions; temperature of the material, type of preheat fuel and type of flames. Each factor plays a definite part in determining the conditions to be used, but the extent is not yet clearly established.

The chemical analysis apparently affects the speed of the reaction, many of the alloy steels requiring noticeably slower speeds than for straight, low-carbon steels. Many of the alloying elements do not oxidize as does iron, and must be removed by the melting action, thus in effect acting as impurities.

Elevation of the temperature of the material aids somewhat in the speed of the reaction, but does not eliminate the need for preheat. Extreme temperature may even make control of the cutting more difficult.

The type of fuel and the type of flames have been subjected to various comparisons, but it appears that if the proper application is made, any of the more prominent fuels can be used with success. This is understandable if we accept the viewpoint that a principal function of the preheat is to heat and to condition the oxygen stream.

Part III—Operating Information

Start of Cut

The starting of the cut on a heavy section has been a problem which has often presented difficulty. The process of establishing the reaction from top to bottom of the material is slower than for thin material, and the actions are more prominent. Some operators are inclined to be hasty in considering that a cut is not starting properly and will stop operations without allowing sufficient time to permit the action to become stabilized. If correct operating conditions are established, there should not be great difficulty in effecting a satisfactory start.

Plate IX portrays some of the conditions which may be observed during the starting period. The corner should be well preheated, Fig. *A*, with the heated zone extending more down the face than on top. A molten zone of from $^1/_2$ to 1 in. is desirable. The tip should be so disposed that the oxygen stream just clears the face. By starting the motion simultaneously with the flow of the oxygen stream, and attaining a normal operating speed immediately, the reaction will take place in a correct manner.

If the tip is too far over the work and the top is heated rather than the face, as in Fig. *B*, an action will take place as in Fig. *C*. The action will occur on top and the stream will be deflected sharply to the rear. In some instances, the stream will eventually pierce through to the bottom as in Fig. *D*, perhaps leaving an uncut corner at the start.

If the starting speeds are too slow, or if the discharging stream expands too sharply due to the excessive pressure, a condition as shown in Fig. *E* will result. The stream will tend to carry the reaction ahead at too great a rate causing a pocket or shelf, below which the stream may be sharply deflected away from the face. If too little oxygen is supplied, or if the speed is too great, Fig. *F*, the stream will fail to penetrate sufficiently and will be deflected away from the material without any tendency to pierce through to the bottom.

A number of aids to starting have been used with varying degrees of success. These include undercutting, torch inclination or slow speeds. Advantages may exist in specific instances, but commercially, such operations are not looked upon with favor unless normal procedure is found to be unsatisfactory, since they complicate the procedure.

The use of the lower pressure cutting streams tends toward better starts, although excessively low pressures may not carry through to the bottom satisfactorily in very heavy work. The higher pressures are more sub-

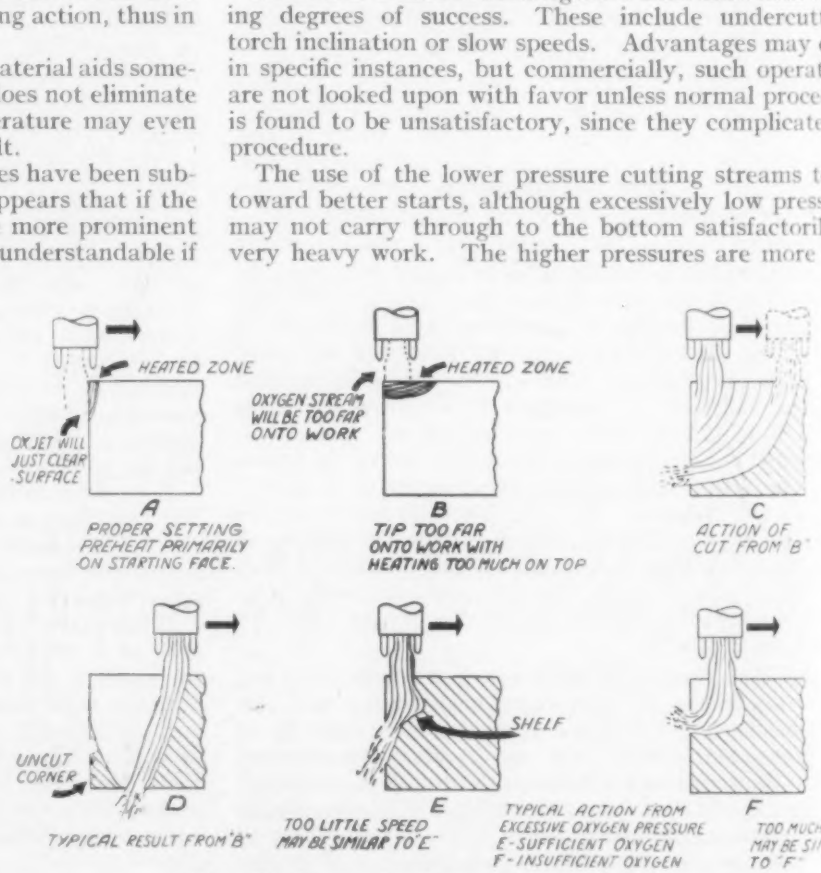


Plate IX—Starting Conditions for Heavy Operations

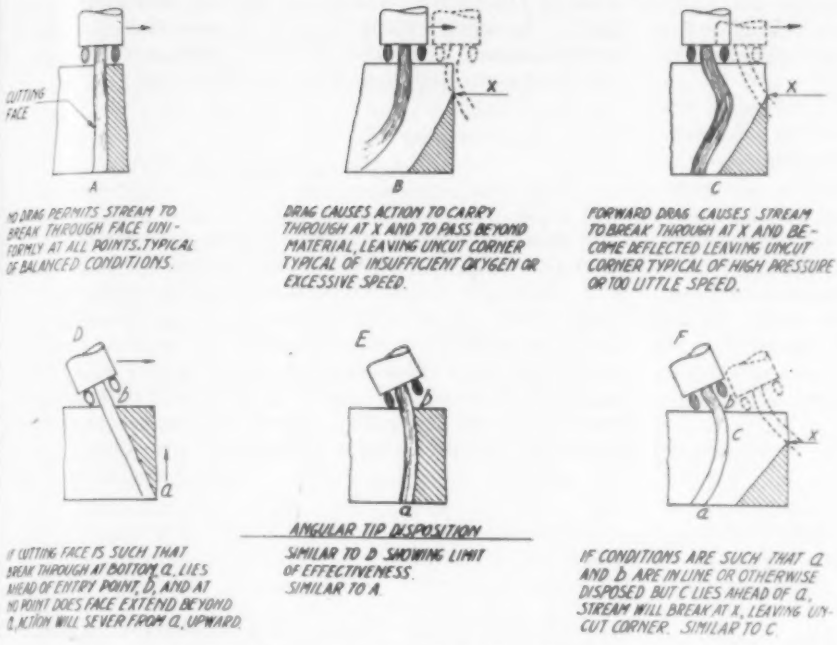

CUTTING FACE
A
NO DRAG PERMITS STREAM TO BREAK THROUGH FACE UNIFORMLY AT ALL POINTS. TYPICAL OF BALANCED CONDITIONS.
X
B
DRAG CAUSES ACTION TO CARRY THROUGH AT X AND TO PASS BEYOND MATERIAL, LEAVING UNCUT CORNER TYPICAL OF INSUFFICIENT OXYGEN OR EXCESSIVE SPEED.
X
C
FORWARD DRAG CAUSES STREAM TO BREAK THROUGH AT X AND BECOME DEFLECTED LEAVING UNCUT CORNER TYPICAL OF HIGH PRESSURE OR TOO LITTLE SPEED.
D
b
a
IF CUTTING FACE IS SUCH THAT BREAK THROUGH AT BOTTOM, a, LIES AHEAD OF ENTRY POINT, D, AND AT NO POINT DOES FACE EXTEND BEYOND a, ACTION WILL SEVER FROM a, UPWARD.
E
b
a
ANGULAR TIP DISPOSITION
SIMILAR TO D SHOWING LIMIT OF EFFECTIVENESS. SIMILAR TO A.
F
b
c
X
a
IF CONDITIONS ARE SUCH THAT a AND b ARE IN LINE OR OTHERWISE DISPOSED BUT c LIES AHEAD OF a, STREAM WILL BREAK AT X, LEAVING UNCUT CORNER. SIMILAR TO C.

Plate X–Finish Conditions for Heavy Operations

ject to sharp reactions and disturbances which are not easy to control.

Finish of Cut

In finishing a cut it is evident again that if the proper balance of operating conditions exists, drop cuts can be obtained even with very heavy sections without resorting to special techniques. A cut in which the line of action is perpendicular to the top and is devoid of a forward drag condition will produce satisfactory finish conditions.

Plate X covers some of the conditions with respect to the finish of the cut. In Fig. *A* the cutting action is as just mentioned. The oxygen stream will break through simultaneously at all points. In Fig. *B* the cut is shown as having a heavy drag. The stream will break through to some point, *X*, leaving a considerable uncut corner. In Fig. *C*, the cut is shown as having considerable forward drag. The stream will break through at a point *X* and after severing the section above this point, will cease action, leaving an uncut corner. In Fig. *D* a torch inclination is shown. If the cutting face is straight, similar to Fig. *A*, the cut will break through at the bottom and continue to the top. The stream may be deflected to a condition as shown in Fig. *E* where the action is paralleled to the finish face. However, if the action is as shown in Fig. *F*, having a rearward path, the stream will break through at *X* and will leave an uncut corner.

Operating Recommendations

The relations which have been conducive to the most satisfactory performance have been listed in tabular form, Table 9. The values revolve about the condition of oxygen flow, therefore, speed is not shown. The presumption is made that initial selection of equipment will be made with the technical characteristics in mind so that the torch will be adequate in capacity. Speed recommendations will lie between 2 and 6 in. per minute for the range covered, 3 in. per minute being a speed which can be used up to at least 36-in. material.

The tabulations cover a range of 12 in. and over and show the range of flow, the range of tip sizes and the range of pressures to use. As mentioned previously, a flow range based on 100*T* is a generally satisfactory starting point, but particularly for heavier work, the relation 120*T* may prove more suitable. The orifice sizes are based upon those which will permit the required oxygen outflow within a pressure range of about 25 to 50 psi. torch entry. The type of orifice to which these data are applicable is shown in the insert.

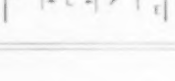
For example, for 36-in material, the intermediate relation of 100*T* shows 3600 cfh. required, which can be obtained from orifice sizes ranging from 0.290 to 0.375 at the pressure listed. For the higher relation, 120*T*, 4500 cfh. is required which can be obtained within an orifice range 0.332 to 0.422 in. at the pressures shown. The speeds will be adjusted in relation to the performance observed within the kerf but can be started at about 3 in. per minute.

Table 9—Operating Recommendations for Heavy Operations

THICKNESS RANGE BASIS			FLOW	CUTTING ORIFICE DIAMETER									
80T	100T	120T		.147	.1695	.1935	.221	.250	.290	.332	.375	.422	.468
12	10	8	1000	56	39	28	—	—					
14½	12	9½	1200	—	49	35	26	—	—				
17	14	11	1400	—	59	42	31	—	—				
19	16	13	1600	—	—	49	36	27	—				
21½	18	14½	1800		—	57	42	31	—	—			
24	20	16	2000		—	—	48	35	25	—			
27	22	17½	2200			—	53	39	28	—			
29	24	19	2400			—	—	44	31	—			
31½	26	21	2600				—	49	34	24	—		
33½	28	22½	2800				—	54	37	26	—		
36	30	24	3000					—	40	29	—		
38½	32	25½	3200					—	43	31	—		
41	34	27	3400					—	47	33	25	—	
43	36	29	3600						50	36	27	—	
45½	38	30½	3800						54	38	29	—	
48	40	32	4000						—	40	30	—	
	42	33½	4200						—	43	32	24	—
	44	35	4400						—	45	34	25	—
	46	37	4600							48	36	27	—
	48	38½	4800							50	38	28	—
		40	5000							53	40	30	—
		41½	5200								42	31	24
		43	5400							—	44	32	25
		45	5600								46	34	26
		46½	5800								48	35	27
		48	6000								50	37	28

OPERATING PRESSURES PSI AT TORCH ENTRY

ORIFICE TYPE
L = APPROX. 10 D
E = APPROX. 2 D
O = APPROX. 120°



Resumé

It is apparent that with a suitable balance of operating conditions, the cutting of heavy sections is not particularly different fundamentally than the cutting of moderate sections although a different perspective must be

applied and the operator must be more alert to conditions and to indications of performance. Without a proper balance, results will be uncertain and may lead to fallacious conclusions.

Of particular importance is an understanding of the general effect of the various factors, and the establishment of definite technical information relating to the equipment in use. Because a particular type of equipment has proved itself capable of use in progressively heavier fields over the years is no assurance that a limit may not be reached.

The successful severance of heavy sections is of more importance than slight economies, hence some of the finer points of comparison common with the cutting of thin sections lose their value as the thickness increases. There is no economy in ruining an expensive heavy section.

Continued studies in this field will serve to definitize some of the factors which are not yet thoroughly evaluated. To what extent improved operation is to be expected cannot be predicted, but it does not appear tenable that any phenomenal results will occur.

Acknowledgment

It would be hardly proper to close without expressing gratitude to J. J. Crowe for his supervisory assistance; J. T. Kennelly for his assistance in the conduct of the many tests; G. M. Deming and J. K. Hamilton for their cooperation in the discussion of various technical detail; Dr. G. V. Slottman, A. H. Yoch and R. F. Helmkamp for their advice pertaining to application and field problems; and the many others who have contributed their efforts in the solution of individual problems.

American Bureau of Shipping Meeting

THE Semi-Annual Meeting of the Board of Managers of the American Bureau of Shipping was held Aug. 1st in the board room of the Bureau at 47 Beaver St., New York City.

President J. Lewis Luckenbach presided, and in his remarks stated:

At our last meeting a report was submitted to the Board on structural failures being experienced on our welded ships. That no serious failures have been reported for some time is in a large measure due to the better weather and temperature conditions prevailing during the summer season, although we have every reason to believe that the corrective measures being carried out on these ships as opportunity affords has also been instrumental in preventing such casualties. The reports of the Senate and House Committees which investigated the structural failures on welded ships have now been published and the interim report of the Board appointed by the late Secretary Knox to investigate the design and methods of construction of welded steel merchant vessels has also been released for publication.

The large amount of investigation work now under way in connection with welding problems is making satisfactory progress. Most of this welding research is under the auspices of the National Defense Research Committee with funds provided by the Government and by the Welding Research Council but some of the projects are being sponsored by the Maritime Commission and the Navy Department. Important investigation work is also being carried out by some of our private shipbuilders, by the steel manufacturers and the Bureau staff in our own laboratory. A special Sub-Committee of the Board to Investigate the Design and Methods of Construction of Welded Steel Merchant Vessels has recently been appointed for the purpose of correlating all the various welding research projects now under way. The Bureau is represented on this and other committees and our contribution to these important activities adds to the work of an already overburdened Technical Staff. In order to help out in this situation the services of Dr. Wendell F. Hess of Rensselaer Polytechnic Institute have been retained by the Bureau as a consultant on matters relating to welding research.

Production of merchant types of seagoing vessels over 2000 gross tons by American shipyards during the first 6 mo. of 1944 has about equaled the results achieved during the first 6 mo. of 1943. However, the production is not comparable with the outstanding record in the latter half of 1943. The tremendous production in the last 6 mo. of 1943 will no doubt stand as an all-time high in the world history of shipbuilding. This rapid rate of construction would have continued into the present year were it not for the curbing of overtime and the necessity for changing over from the comparatively simple type of Liberty ship to the more involved Victory type. The transition, however, has been accomplished with the minimum of lost time, so that by the end of this year American shipyards will have completed a record number of high-speed competitive types of merchantmen.

Between January 1st and June 30th, American shipyards completed 723 large merchant ships of 5,606,112 gross tons and a deadweight carrying capacity of 8,239,234 tons, having propulsion machinery totaling 3,321,960 hp. American merchant ship production, 1939 to date, has reached a total of 3284 vessels of 24,979,476 gross tons, 36,731,891 deadweight tons and 12,773,812 hp. This merchant fleet produced almost entirely in the midst of a war is almost three times greater in number than what existed under the American Flag in 1939, and almost four times greater in gross tonnage and deadweight. Deducting war losses of American Flag tonnage, we now have merchant vessels double in number and tonnage than what existed prewar under the British Flag, at that time the first ranking maritime nation. In fact, our fleet now is approximately equal to one-half of the prewar world tonnage. Deducting world sinkings, America now owns the major part of world merchant tonnage.

In new construction, the trend is toward larger vessels with greater carrying capacity and more speed. The average ship built in the last war was 5100 gross tons and the present average is about 7600 gross tons. Exclusive of Liberty ships they have greatly increased horsepowers and more than 50% greater speed. Most of the vessels being built today will provide valuable earning tools in the postwar period.

Of the total production for the first 6 mo. of 1944, 586 vessels of 4,241,663 gross tons and 6,128,988 deadweight tons were cargo ships. Of this number, 435 were

Liberty ships. Only 410 Liberty ships remain under contract to be constructed and all of these should be finished early next year. A total of 2279 Liberty ships has been completed since the first one was finished in Dec. 1941. These vessels have been produced in an average time of 62.7 days each. The performance of our shipyards in building Liberty ships contributed greatly to consummating the greatest industrial and military accomplishment of the ages. Pacific Coast shipyards have completed their Liberty ship contracts, and this type of vessel is now being constructed only in Atlantic and Gulf Coast shipyards.

The Victory type cargo ship is now being constructed by six shipyards, five of which are on the Pacific Coast. Building time is being rapidly reduced with each successive vessel. In one yard the time of 60 days for producing a Victory ship from keel laying to delivery was reached on the 28th ship, whereas this record of 60 days with the Libertys in the same shipyard was not reached until the 34th ship. This, in spite of the fact that a Victory ship is almost 20 ft. longer, almost 6 ft. more beam, is deeper and has more than three times the horsepower, as well as many other refinements, such as electric cargo handling appliances, etc. The *Poland Victory* the first ship of this type to complete a trip around the world has just arrived on the East Coast and most glowing reports on her performance have been received.

Additions to our tanker fleet during the first 6 mo. of this year totalled 118 units of 1,215, 536 gross tons and 1,929,415 deadweight tons. This rate of production is scheduled to continue throughout the year, so that we will have constructed more tanker capacity than was ever produced before in the world's history in 1 yr. These tank ships added to our tanker fleet, plus the tankers on order yet to be completed, less sinkings, will come close to equaling in capacity the entire world tanker fleet existing before the war. Certainly it is twice as large as any tank fleet existing under one flag today. All of the units constructed this year to date are of large capacity, over 16,000 tons, having speeds ranging from 16 to 18 knots.

America, the largest shipbuilding nation in the world today, is producing ships at the rate of about 28 per week exclusive of a vast Navy program. The ships produced today are generally more modern and better suited for postwar needs than those produced a year ago. The Liberty ship, which was built essentially for purposes of war, has served its purpose magnificently, and that program is nearing completion.

American ships cost a great deal more to build than comparable ships from foreign yards. In order that the American shipowner may compete, the difference in cost of the vessel and cost of operation, which takes in wages, etc., to some degree is compensated for by what is often called a subsidy. The fact of the matter is that our standard of living is high and we are determined not to injure it. To preserve that standard of living the Government pays a portion of the differential in costs. American labor receives high wages and the American seaman during the last few dangerous years has proved himself certainly worthy of recognition and support.

During the last war almost no modern tonnage was available. Fortunately because of the establishment of the Maritime Commission in 1936 a policy was laid down which was capable of tremendous expansion so that an adequate number of vessels have been available to carry munitions and goods to the fighting fronts. Such a policy should be vigorously supported so that an American shipping industry will thrive over a period of years instead of being spasmodic and an unsatisfactory arm of our national defense. It is essential that the up-to-date facilities that have been established be kept in use and it is particularly important that the technical skills which have been developed not be allowed to deteriorate.

With the approach of peace, the question of the preservation of our Merchant Marine after the war should be given serious attention not only by shipping men but by all Americans. The vital necessity of a Merchant Marine in time of war has been proved more than once and that factor alone should be so potent that the American people will never again consent to have the Merchant Marine deteriorate as it did after the last war.

Our foreign trade must be increased by supplying the nations of the world with American goods and in return buying from other nations imports which will provide cargoes for return voyages of American ships. It is a depressing fact that the decline in foreign trade among all nations has been steady and severe in the last 40 yr. In spite of greatly increased production, nations are striving for economic self-sufficiency so that world trade has since 1913 up to 1938 decreased probably over 30%. The foreign trade of the world should be immeasurably increased and American ships should carry their fair share of this increased trade.

The people of the United States should be aware of these facts in order that they may get behind a broad shipping policy which is so vital to the existence of our country as a world power. Not only in coastal districts but in the Midwest, the people should realize that a vitalized Merchant Marine is necessary and they should support it. Other nations are preparing extensively for postwar shipping activities. We are lagging, and if we do not take positive action we may expect to have a situation similar to that following the last war.

If the ship owners, the shipbuilders, repair men and other people in shipping, which today is one of the great industries, do not get together and urge its support and give the many reasons why the Merchant Marine of the United States is so essential to defense as well as our national welfare it will slip back in its old place. We shall have no one to blame but ourselves. Much is being said, there is a great deal of wishful thinking and some things are being done—but not enough.

Current Welding Literature

(Continued from page 905)

Valves and Valve Gears. Arc Welded Back Pressure Relief Valve. Power Plant Eng., vol. 48, no. 6 (June 1944), pp. 97–98.

Valves and Valve Gears, Hard Facing. Application of "Stellite" to Worn Valve Seats. Engineering, vol. 157, no. 4080 (Mar. 24, 1944), p. 240.

Welded Structures of Varied Types Indicate Wide Range of Post-War Uses. Construction Methods, vol. 26, no. 6 (June 1944), p. 57.

Welders, Ability Testing. Testing Welding Operator Ability, R. M. Gooderham. Can. Machy., vol. 55, no. 5 (May 1944), pp. 109–110, 112, 114, 144.

Welders. Health Hazards Associated with Welding, F. W. Hutchinson. Heating & Vent., vol. 41, no. 5 (May 1944), pp. 73–77.

Welders, Training. Notes on Training of Oxy-Acetylene Welders, C. G. Bainbridge. Sheet Metal Industries, vol. 19, no. 205 (May 1944), pp. 873–877; no. 206 (June) pp. 1063–1064, 1070.

THE AMERICAN WELDING SOCIETY

ACTIVITIES — RELATED EVENTS

AMERICAN WELDING SOCIETY TO HOLD TWENTY-FIFTH ANNUAL MEETING

Seventeen technical sessions embracing more than sixty papers on welding subjects will feature the 25th Annual Meeting of the AMERICAN WELDING SOCIETY to be held in the Hotel Cleveland, Cleveland, Ohio, from October 16th to 19th. The meeting is being held, as in past years, in conjunction with the National Metal Congress.

Two talks emphasizing the importance of welding in meeting the wartime production needs of the nation will be delivered at the opening session on the morning of October 16th. Rear Admiral H. L. Vickery, U. S. Maritime Commission, will speak concerning the use of welding in shipbuilding; and Colonel S. B. Ritchie, U. S. Army, of its use in the fabrication of ordnance equipment. The work of the AMERICAN WELDING SOCIETY in promoting the production of needed ordnance equipment will be recognized by the presentation of the Ordnance Distinguished Service Award at this session. According to the Chief of Ordnance, United States War Department, the award is being made as a recognition of the "outstanding contributions" of the SOCIETY and because of its scientific and engineering achievements during the war years.

The technical papers to be presented cover the entire range of application of welding and applied processes, emphasizing wartime applications. Most of these applications and developments will be of importance when industry returns to normal peacetime production. The men who have prepared the papers represent the thinking of those interested in production, supply, engineering and research.

RULES FOR FUSION WELDING PIPING IN MARINE CONSTRUCTION

Those engaged in the present large-scale shipbuilding program will be interested in the "Rules for Fusion Welding Piping in Marine Construction" published by the AMERICAN WELDING SOCIETY.

First published in 1938, this standard has now been revised to bring the original data for welding low-carbon steel (0.35% max.) marine piping up to date. Among the topics included are: Qualification of Welding Procedure; Qualification of Welding Operators; Design; Layout and Dimensions of Piping; Allowable Types of Joint; Preheating; Stress-Relieving; Radiographic Tests; and Hydrostatic Tests.

Copies of the standard are available in the form of a 6 x 9 bulletin from the AMERICAN WELDING SOCIETY, 33 West 39th St., New York 18, N. Y., at a price of 25¢ per copy.

ADAM'S LECTURE

The Adams Lecturer this year will be Augustus B. Kinzel, who will lecture on "Solid Phase Welding." This lecture will be presented Monday evening, October 16th, at the Hotel Cleveland, Cleveland, Ohio, in connection with the Annual Meeting of the AMERICAN WELDING SOCIETY.

The Adams Lecture was established in 1943 by the Board of Directors of the AMERICAN WELDING SOCIETY in honor of the founder and first president of the SOCIETY. The 1943 Lecture was presented by Dr. C. A. Adams.

AUGUSTUS B. KINZEL

Dr. Kinzel, Vice-President of Electro Metallurgical Co. and Chief Metallurgist of Union Carbide and Carbon Research Laboratories, Inc., graduated from Columbia University, Massachusetts Institute of Technology and the University of Nancy, France, where he received the degree of Doctor of Science. Before joining the Union Carbide organization in 1926, he had several years of practical experience as metallurgist with General Electric Co. and Henry Disston & Sons, lecturer in advanced courses in metallurgy at Temple University, and as a consultant.

A. B. Kinzel

Dr. Kinzel is the author of many papers on the testing and welding of metals, on the metallurgy and physical chemistry of steel making, on the composition, physical properties and uses of ferro-alloys and alloy steels, and on applied mechanics, and is co-author of the volume on chromium in the "Alloys of Iron" series of monographs. He holds many patents in these fields. Besides being Past Chairman of the Iron and Steel Division of the American Institute of Mining and Metallurgical Engineers and of the New York Chapter of the American Society on Metals, Dr. Kinzel is also Senior Consultant of the Metals Branch of the War Production Board, Special Consultant on Metals of the Economic Warfare Division of the Foreign Economic Administration, Project Supervisor of the War Metallurgy Committee, Chairman of the Advisory Committee of Dynamic Testing Laboratories, M. I. T., Chairman of the Weldability Committee of the Welding Research Council, member of the International Commission for Acetylene and Welding, member of the Committee on Metals of the National Academy of Sciences and Member of the Board of Directors of the Engineering Foundation.

STANLEY TO RECEIVE A.S.M. RESEARCH MEDAL

Robert Crooks Stanley, Chairman and President of The International Nickel Company of Canada, Limited, will receive the A.S.M. Medal for the Advancement of Research during the annual dinner of the American Society for Metals on Thursday evening, October 19th at Cleveland.

Awarded annually to the executive who has consistently sponsored metallurgical developments and by his foresight has helped to advance the arts and sciences relating to metals, Mr. Stanley will receive the 1944 Research Medal because of his pioneering leadership in the field of metals research.

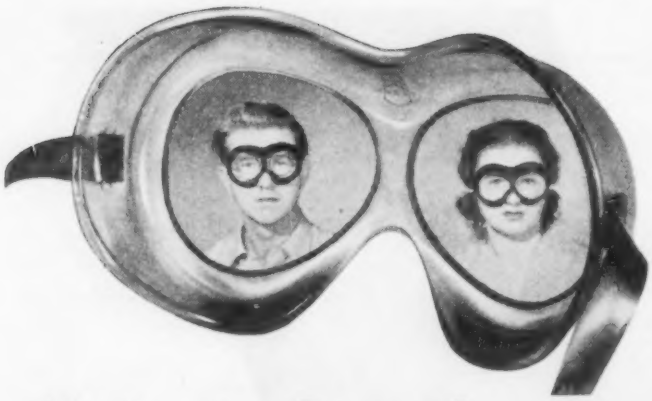
Ordnance Distinguished Service Award

The Award will be made by Col. S. B. Ritchie on Monday morning October 16th

A WELCOME HAND TO BELL SYSTEM WAR VETERANS

Some day we shall have the pleasure of welcoming back to the Bell System the men and women who are now in the armed forces. They number more than 55,000. Some 3500 released from service are already back with us. We shall have a warm welcome for the rest as they join us again. Not only shall we be glad to see them personally but we shall be glad of their skill and energy for the big tasks which face the Bell System in the future.

BELL TELEPHONE SYSTEM



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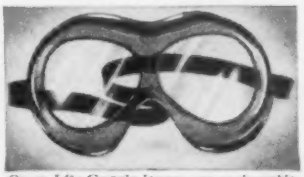

Cover-Lite Goggle lenses are *replaceable*

● As you're looking through these new CESCO *Cover-Lite* Safety Goggles you're practically experiencing their comfort, too. When you actually have them on, you scarcely know they're there.

Why, the combined weight of the lenses and the frame is only 96/100 of an ounce! And, the frame rests lightly on the brow, nose and cheeks —no pressure anywhere. They're comfortably worn over spectacles, too.

Notice the clear plastic, non-shattering, replaceable lenses. They have remarkable strength—and assure safety against impact. Also, the colored plastic frame serves as an eye shade, to eliminate reflections and reduce eye strain. The goggles are available with transparent green (No. 552) or white marbleized (No. 554) frames; also available with green, glare-reducing lenses.

Write for complete information on this amazing, new *Cover-Lite* goggle now.

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INDEX TO ADVERTISERS

Air Reduction Sales Co. . . . . Outside back cover
American Brass Company 983
American Chain & Cable Company, Inc. 989
American Optical Co. 994
American Welding Society 1000
Ampco Metal, Inc. . . . . 1005 & 1006
Anti-Borax Compound Company 970
Arcos Corp. . . . . Inside front cover
Bastian-Blessing Co. 954
Bell Telephone System 945
Champion Rivet Co. 993
Chicago Bridge & Iron Co. 999
Chicago Eye Shield Co. 946
Chicago Steel & Wire Co. 968
The Diversey Corporation 957
Eisler Engineering Co. 954
Electroloy Co., Inc. 958
General Electric Co. . . . . Insert 1002 & 1003
Glenn-Roberts Company 971
Handy & Harman 991
Harnischfeger Corporation 977
Haynes Stellite Co. 872
Hercules Elec. & Mfg. Company, Inc. 950
Hewlett-Packard Company 1001
Hobart Bros. Co. 869
International Nickel Co. 969
Kelley-Koett Mfg. Company 985
Lepel High Frequency Labs. 987
The Lincoln Electric Co. . . . . 948 & 949
The Linde Air Products Company 871
Machlett Laboratories, Inc. 955
Magnaflux Corporation 992
P. R. Mallory & Co., Inc. 973
Metal & Thermit Corporation 963
The Midland Paint & Varnish Co. 964
National Carbide Corporation 966
National Metal Congress 967
Nelson Specialty Welding Equipment Corp. . . . . 960 & 961
Oakite Products, Inc. 968
Page Steel & Wire Division 989
Picker X-Ray Corp . . . . . 974 & 975
Progressive Welder Co. 956
Ransome Machinery Co. 965
The Reid-Avery Company 951
Resistance Welder Mfrs. Association 1004
Sciaky Bros. 996
Shawinigan Products Corp. 956
The Sight Feed Generator Company 962
Sixth War Loan 953
A. O. Smith Corporation 979
Square D Company 981
Stoody Company 997
Tweco Products Company 995
Una Welding, Inc. 947
Union Carbide and Carbon Corp. . . . . 871 & 872
United Welding Company 964
Victor Equipment Co. 959
Weltronic Company 952
Westinghouse Elec. & Mfg. Co. . . Inside back cover

INCREASE YOUR WELDING CAPACITY
2 TO 3
TIMES
WITH UNAMATIC
UNAMATIC FOR FASTER... BETTER LOWER COST with AUTOMATIC WELDING
Above—Shielded arc automatic welding of shipmast on circumferential and longitudinal weld with UNA Wire and Tape—Below—Complete shipmast. Courtesy King Bros., Inc. Portland, Oregon.

UNAMATIC Welding enables plants to turn out 2 to 3 times as much work with the same number of operators, when compared with the manual process. This advantage of increased production, or expressed in another way, *greater fabricating capacity of your plant,* is important not only today but will prove extremely desirable in the keenly competitive postwar market.

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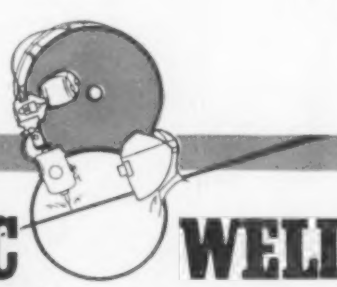

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MIGHTY text for a postwar industrial sermon is that given by Eric Johnston . . . "Beaten Paths are for Beaten Men."

Anyone who has followed, even casually, his able leadership of the U. S. Chamber of Commerce will sense that his fight is for men who can change over from business procedures that simply ECHO, to those that SHOUT!

The trouble is that, to many, departure from the beaten path presents many unknowns which cause hesitation.

But, there is a painless and *known way* to blaze the trail . . .

"Beaten Paths are for Beaten Men," *says Eric Johnston*

Look, Mr. Johnston, how production and construction men are stepping out in front in welding speed and economy with Lincoln "Fleet-Welding":

STEP AWAY FROM THE BEATEN PATH WITH "*FLEET-WELDING*"

Typical actual step-ups in welding speed reported by two fabricators:

350% FASTER BUTT WELDING

"Arc Force" of "Fleet-Welding" makes possible square edge butt joints and two-pass welding of plate as heavy as ⅜". . . 9" of joint per min., compared to 2" per min. with conventional technique . . . a Pittsburgh Tank Builder.

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"Fleet-Welding" digs into the corner . . . in the case of ½" plate, cuts the amount of deposited metal by 50% and boosts welding speed from 5" per minute to 12" per minute. Cuts cost 59% . . . a Cleveland Structural Fabricator.

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ARC WELDING

OUR NEW PRESIDENT

A. C. Weigel

"Al," as he is known to all of his friends, was born July 13, 1887. He graduated from the University of Tennessee in 1908. He joined the Walsh & Weidner Boiler Co. and remained with them until its acquisition by Combustion Engineering Co. in 1928. He has been with the latter organization ever since. At present he is Vice-President of this company.

A. C. Weigel

Mr. Weigel, in addition to being a member of the SOCIETY and its Executive Committee, is also a member of the A.S.M.E. Boiler Code Committee, Newcomen Society and other technical societies. At present, he is President of the American Boiler Manufacturers Association and Affiliated Industries.

During the past three years Mr. Weigel has served as Chairman of the Publications Committee of the SOCIETY.

"Al" Weigel possesses rare judgment and tact and is an outstanding executive. He is keenly interested in welding matters and in the SOCIETY. He is active in the work of the Welding Research Council and is a member of its Executive Committee. He is also active in its financial affairs. His interest in welding started prior to the sanction of the use of Welding by the Boiler Code Committee, when we were making extensive studies and investigations to assist in the protective requirements of the Code.

Isaac Harter

OUR FIRST VICE-PRESIDENT

Isaac Harter

Mr. Isaac Harter, now vice-president of The Babcock & Wilcox Co., Barberton, Ohio, was born at Mansfield, Ohio, in 1880. He graduated in 1901 from the University of Pennsylvania with the degree of B.S. He began work that year in the Boiler Department of Aultman & Taylor Co. at Mansfield. In 1905 the Stirling Co. at Barberton, Ohio, bought the business at Mansfield and in 1906 it was in turn acquired by The Babcock & Wilcox Co., by whom he has been employed since that time in various capacities in manufacture, plant construction and technical and business development.

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Power cost 50% lower than motor generators. No rotating parts at all, therefore supervision, oiling, replacement of wearing parts eliminated.

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Continuous 24 hour per day operation. Sturdy connectors, on-off switch or circuit breaker for lifetime of wear. Spun glass insulation. Durable sheet-steel housing. Easy rolling, portable.

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RACO 11	E-6011	Mild Steel	All Position	A.C.
RACO 8	E-6012	Mild Steel	General Purpose Poor Fit-up	Str. Pol. or A.C.
RACO 8	E-6013	Mild Steel	General Purpose Light Gauge	Str. Pol. or A.C.
RACO 6	E-6020	Mild Steel	Butts, Positioned Fillets and Deep Grooves	A.C. or D.C.
RACO 20	E-6030	Mild Steel	Single Pass - Fillets or Grooves	A.C. or D.C.
RACO 5	E-6020 E-6030	Mild Steel	Deep Grooves	A.C. or D.C.
RACO 82	E-6030	Mild Steel	All Position Wear-resisting Machinable	Str. Pol. or A.C.
RACO 74	None	Steel	All Position	Rev. Pol.
RACO 64	E-7010	High Strength Steels	Butts, Positioned Fillets and Deep Grooves	A.C. or D.C.
RACO 13	E-7020 E-7030	High Strength and Silicon-killed Steels	General Purpose Poor Fit-up	A.C. or D.C.
TYPE D	E-6013	Mild Steel	Automatic or Manual	Str. Pol.
TYPE D 30-40 C	E-4511 E-4521	Mild Steel	Automatic or Manual, Wear-resisting Machinable	Str. Pol.
TYPE M	None	Steel	Automatic or Manual	Str. Pol.
BLUE LABEL	E-4511 E-4521	Mild Steel	Manual	Str. Pol.
RACOLLOY 19-9	E-4510 E-4520	Mild Steel	Welding and Surfacing	Rev. Pol. or A.C.
RACOLLOY 25-20	None	Stainless and Air-Hardening Steels	Welding and Surfacing	Rev. Pol. or A.C.
	None	Stainless and Air-Hardening Steels		

The

REID-AVERY COMPANY

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SINCE 1919 • PRODUCERS OF ARC WELDING ELECTRODES AND WELDING RODS

electronic Weltronic bulletins

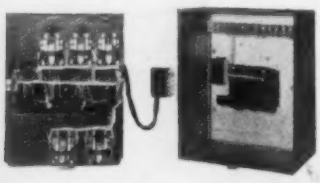
SIMPLER TIMER CIRCUITS CUT COSTS

Not only are fewer and less expensive tubes used in Weltronic timing circuits, but their simplicity also reduces maintenance of welding control to a minimum. Inspection is easier, tube replacement is reduced and machine down-time minimized through this exclusive Weltronic development. As many as one-third of the tubes required by conventional timers have been eliminated on many models without any sacrifice in precision of timing.

Use of 'grid blocking' transformers in the timing circuits makes the controls less sensitive to power line variations which often cause inconsistent timing with conventional controls.

There is a simple Weltronic Timer for every resistance welding control application.

Ask for Bulletin No. WTT-44



Weltronic COMPANY

DETROIT 19, MICH.

His interest in welding began with experiments in 1907 in repairing steel castings with a carbon arc. From 1911 to 1914 he was instrumental in investigating several serious cases of caustic embrittlement, and, as a result, brought about a radical change in boiler water treatment in the U.S.N. and a general interest in the modifying effects of sodium sulphate in these cases. His company made use of bare wire welding in boiler drums from 1922 to 1929 at the ends of the main longitudinal seams and then led the way in the manufacture and sale of completely welded boiler drums. He was closely associated with the beginnings of the A.S.M.E. Boiler Code and the corresponding Code of the State of Ohio, and with the acceptance by the U.S.N. of welding for its pressure vessels. In 1931 he became responsible to his company for the construction and installation of the 30-ft. penstocks at Boulder Dam, a project impossible to realize without the art of welding. He has guided the development of its business in kaolin refractories, in the production of alloy steels for its own use, and more recently for its work in the production of electrically welded tubes.

OUR SECOND VICE-PRESIDENT

W. F. Hess

Dr. W. F. Hess attended Rensselaer Polytechnic Institute at Troy, N. Y., for four years, graduating in 1925 with the degree E.E.; did graduate study at R.P.I. for three years ending 1928 with the degree D.Eng.; was instructor in Electrical Engineering and Physics, R.P.I., 1928 to 1930. In 1929 Dr. Hess began teaching a course in welding to United States Navy Annapolis graduates sent to R.P.I. by the Bureau of Yards and Docks for special training, which has been continued since that date. He was Assistant Professor of Electrical Engineering and Physics, 1930 to 1937; New York State licensed Professional Engineer No. 13793 since August 13, 1935; Assistant Professor in Metallurgical Engineering, 1937 to 1938.

In 1937, Dr. Hess designed and arranged for the equipment of the present welding laboratory at R.P.I. In 1938 the First Welding Research Committee Fellowship was established for the study of the spot welding of low-carbon and stainless steels. This fellowship was renewed until the present year. From 1938 until the present time, he has been Associate Professor in Metallurgical Engineering and Head of Welding Laboratory.

In 1939 the International Nickel Co. established a Resistance Welding Fellowship, which was continued until the present year.

Establishment of first Aircraft Spot Welding Research Fellowships under the auspices of the National Advisory Committee for Aeronautics, the Army Air Corps and Navy Bureau of Aeronautics were made in 1940 and continued until the present year.

Establishment of first programs of War Research under the War Metallurgy Committee of the National Research Council was made in 1942 and continued until the present.

W. F. Hess

In 1944 came the establishment of first programs of war research under the Office of Production Research and Development of the War Production Board. Dr. Hess is also consultant on welding problems to the American Bureau of Shipping.

Dr. Hess has held the following offices in the SOCIETY: Chairman, Northern New York Section; District Vice-President, New York and New England district; Chairman, Committee on Awards; and Present Chairman, Educational Committee. He is a member of A.W.S., A.I.E.E., S.P.E.E. and A.S.M.

OUR TREASURER

O. B. J. Fraser

Mr. O. B. J. Fraser is relatively a newcomer with the AMERICAN WELDING SOCIETY, having joined in 1935. In this short space of time he has established him-

O. B. J. Fraser

PLAN YOUR PLANT DRIVE NOW!

Good organization will be needed to sell the 6th. The task of raising the huge sum required will be the most difficult ever asked of Industry. As each new military success brings us closer to Victory, the public naturally will feel that the urgency of war financing is lessened—whereas it isn't. So organize now to prevent a letdown on the home-front from causing a letdown on the fighting front. Build your plant's payroll campaign around this fighting 8-Point Plan. You don't have to wait for the official Drive to start—swing into action NOW!

1 **BOND COMMITTEE**—Appoint a 6th War Loan Bond Committee from labor, management and each representative group of the firm.

2 **TEAM CAPTAINS**—Select a team captain, for each 10 workers, from men and women on the payroll—but not in a supervisory capacity. Returned veterans make most effective captains.

3 **QUOTA**—Set a quota for each department and each employee.

4 **MEETING OF CAPTAINS**—Give a powerful presentation of the importance of the work assigned to them. Instruct them in sales procedure. Have them carefully study the Treasury Booklet, *Getting the Order.*

5 **ASSIGNMENTS**—Assign responsibilities for:

(a) *Music, speeches and announcements of the opening rally.*
(b) *Pre-drive letter to employees from management and labor.*
(c) *Competitive progress boards.*
(d) *Meeting schedules, etc.*

6 **CARD FOR EACH WORKER**—Dignify each personal approach with a pledge, order, or authorization card made out in the name of each worker. Provide for a cash purchase or installment pledge. Instruct each captain to put a pencil notation on the card to indicate the subscription he expects to solicit from each worker.

7 **RESOLICITATION**—People don't mind being asked to buy more than once. Resolicit each employee toward the end of the drive in a fast mop-up campaign. Call upon your State Payroll Chairman; he's ready with a fully detailed plan—NOW!

8 **ADVERTISE THE DRIVE**—Use all possible space in the regular media you employ to tell the War Bond story.

The Treasury Department acknowledges with appreciation the publication of this message by

THE WELDING JOURNAL

This is an official U. S. Treasury advertisement prepared under the auspices of Treasury Department and War Advertising Council

self as one of the hardest workers of the SOCIETY. He is Chairman of the Nickel Alloys Committee of the Welding Research Council. He has served as a member of the Executive Committee of the SOCIETY and a member of the Committee on Outline of Work. He served also as chairman of the Meetings and Papers Committee and of the Committee to Study the Reorganization of the Technical Activities of the SOCIETY. His good judgment and genial disposition and his broad experience make him a decided asset to the SOCIETY.

O. B. J., as his friends choose to call him, was born in Brockville, Ontario, Canada. He received the B.Sc. degree in Metallurgical Engineering in 1916 from Queen's University, Kingston, Ontario. He spent a year inspecting military explosives. He joined the International Nickel Co., Inc., in the summer of 1917 at their works in Bayonne, N. J. From then until 1922 he occupied several positions at the Port Colborne, Ontario, Works of the company, as superintendent of the electrostatic fume precipitation plant, as night works superintendent and research engineer. In 1922 and 1923 he became connected with Mellon Institute in the study of corrosion of nickel and nickel alloys. From 1924 to 1932 he was in charge of the research laboratories of the International Nickel Co. at Bayonne. From 1933 to 1934 he carried on field development work in the use of nickel alloys in the petroleum industry. From 1934 to date he has served as Director of Technical Service on the International Nickel Company's mill products, which include welding service work on nickel, nickel-copper and nickel-chromium iron alloys and on steel clad with these alloys.

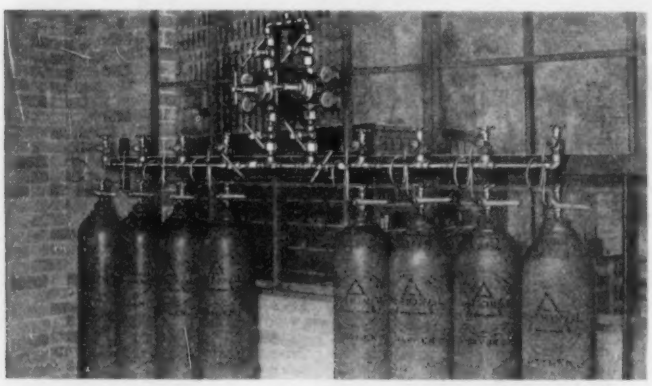
DIRECTORS-AT-LARGE

Roger W. Clark

Mr. Roger Clark, reelected as Director, was born in Paxton, Mass., in 1902 and attended Clark University in Worcester, Mass. Roger is one of the hardest committee workers of the SOCIETY. He is Chairman of the Committee on Outline of Work, Chairman of the Committee on Definitions and Chart, and member of half a dozen technical committees of the SOCIETY. He has also been active in standardization work of the A.S.A. and the A.S.T.M. He is past chairman of the Northern New York Section of the SOCIETY and has been a member of the Executive Committee of the SOCIETY during the past year. He is also Chairman of the A.W.S. Ordnance Committee.

Roger joined the General Electric Co. when he left Clark University in January 1924. A year later he became identified with welding in the General Electric Co. and during the next three years he was active in production welding, supervision and inspection. In 1928 he entered the Works Laboratory and was assigned to the problem of setting up engineering standards on welding. He has also been active in training and qualification of welding operators and the development of welding procedures and procedure control for the General Electric Co.

R. W. Clark



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Conserve your equipment. You may not get more.

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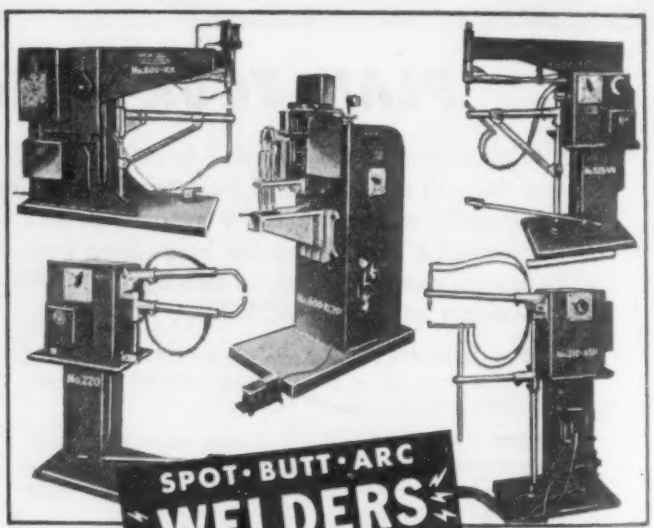
Pioneers and Manufacturers of Precision Equipment for Using and Controlling High Pressure Gases



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We manufacture a complete line of resistance spot welders from ¼ to 300 KVA for all types of welding. There is an EISLER WELDER for every purpose.

TRANSFORMERS OF ALL TYPES

WE INVITE CONTRACT SPOT WELDING IN LARGE OR SMALL QUANTITIES.

CHAS. EISLER
EISLER ENGINEERING CO.
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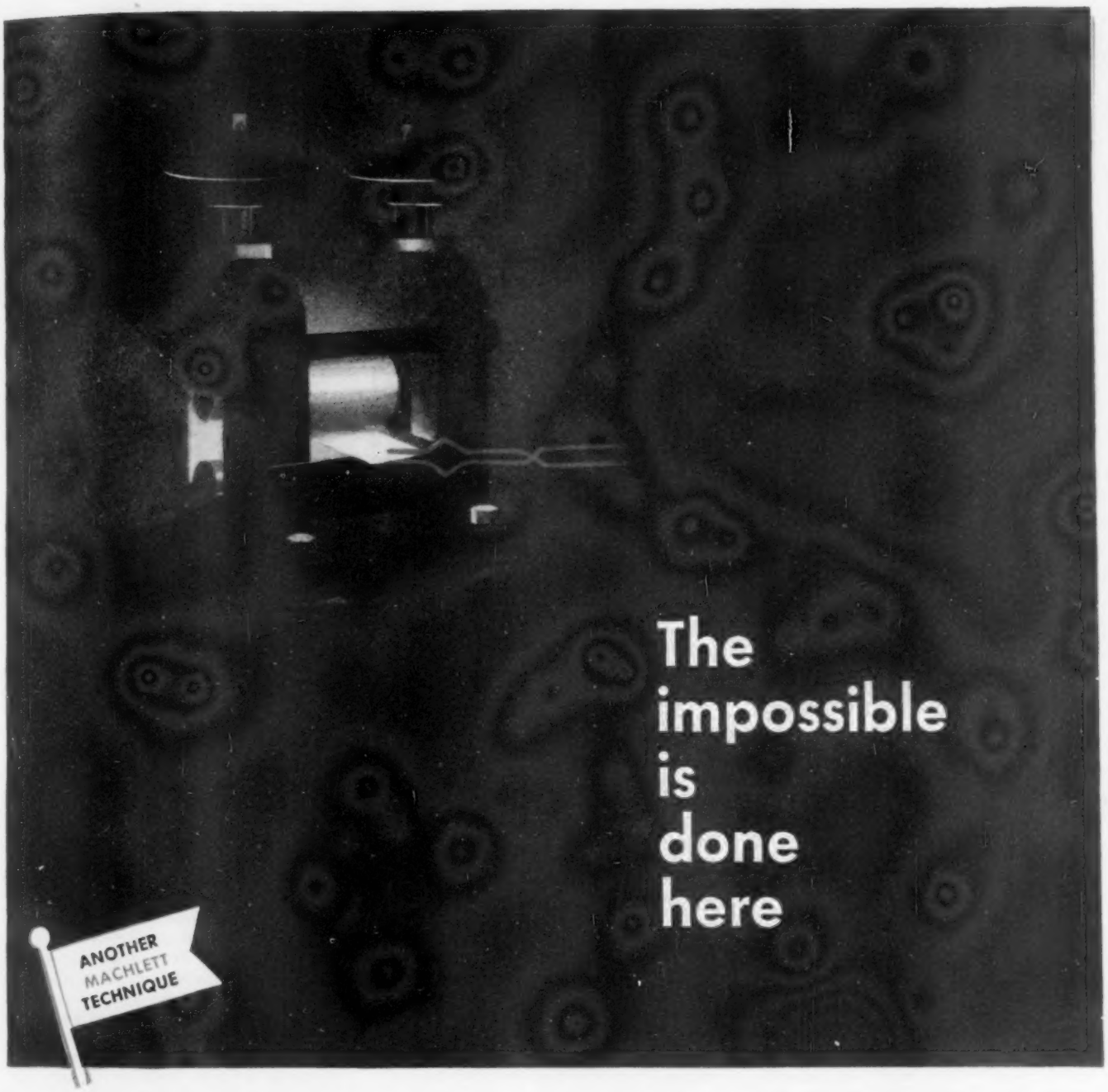

This simple operation is the final proof that Machlett has succeeded in producing malleable beryllium, for here that metal is being rolled into sheets from 0.004 to 0.020 inch thick, sheets that are vacuum-tight, and have adequate ductility at high temperatures. Such properties were once considered impossible to realize.

Why was it important to produce the metal in this rare form? Because beryllium was known to be remarkably transparent to X-rays, and if it could be used as a window in the tube envelope, a great improvement would be made in tubes for several important applications — particularly X-ray diffraction. One such application is determining the axes of quartz crystals (important in war radio); there are manifold similar vital technical uses in metallography.

So Machlett did the impossible — beryllium was made malleable. Details are to be found in a scientific paper, copies of which will be sent on request.

Such an achievement is typical of the Machlett determination to overcome even the greatest obstacles to the production of the most effective and desirable types of vacuum tubes, whether they be X-ray tubes for medical, dental, industrial or scientific purposes, or are radio tubes for communications or induction heating. When you see the Machlett name, remember that it was the policy of making the best possible product that made us the world's largest manufacturer of X-ray tubes . . . Machlett Laboratories, Inc., Springdale, Connecticut.

Machlett Diffraction Tube with beryllium window. Used in analyzing quartz crystals for war and other radio purposes, and in metallography.

MACHLETT

X RAY TUBES SINCE 1898

TODAY THEIR LARGEST MAKER

L. W. Delhi

Mr. Delhi was born in Arizona, November 1892, and is of Danish extraction. He attended Throop Polytechnic and U.S.C. Mr. Delhi was unable to complete his university work and turned to professional baseball for four years before resuming engineering with the Nevada Consolidated Copper Co., at Ray, Arizona, which position he held for four years. He then spent three years in engineering work and contracting in Southern California and about

L. W. Delhi

sixteen years ago joined the Western Pipe & Steel Co. He is a member of the Olympic Club, Lakeside Golf & Country Club, Astronomical Society of the Pacific and the Seismological Society. It may be added that for the entire sixteen-year period with the Western Pipe & Steel Co. the major problem has been the sales, engineering and mechanical development of welded products. Mr. Delhi is Vice-President of the Western Pipe & Steel Company.

James Finney Lincoln

James Finney Lincoln, President of The Lincoln Electric Co., Cleveland, Ohio, and the man in whose honor The James F. Lincoln Arc Welding Foundation was created, was born May 14, 1883, on a farm near Painesville, Ohio.

J. F. Lincoln

His academic training for the profession of electrical engineering was obtained at Ohio State University. He left school early in 1907 a few months before he was to graduate, a victim of the then-prevailing epidemic of typhoid fever. He was later awarded the degree of Electrical Engineer by the faculty. His two older brothers, Paul M. and John C. Lincoln both hold the same degree from Ohio State University.

The character and mental stature of the man to be were evident during his life at the University. He was large and heavily muscled but, unlike many big men, he displayed a tempestuous emotional make-up which brought him devoted followers on the football field and served as a forecast of the way in which he would tackle the problems of life and of his profession.

His older brother, John C. Lincoln, had founded The Lincoln Electric Co. and here is where James F. Lincoln went to work. It required five or six years for the strongly emotional youth to find himself. He finally did so by applying his tremendous energy and enthusiasm to the job of making the developments of electrical engineering useful to the public. That became a consuming passion with him and in following it, he worked in the fields of invention, development, engineering and, lately, the broader fields of economics and industrial management.

Since 1929, the company of which he is now president, has more than tripled its number of employees. The company has no bonded or bank indebtedness and is owned almost entirely by men active in its management and by its wage earners.

This happy state of affairs is due to James F. Lincoln's enthusiasm for applying technical achievements to useful purposes. Among his achievements are the following.

His first contact with electric arc welding was made when a 400-amp. arc-welding set sold for something aroung $3000 or $4000. He brought about the development of the separately excited d.-c. arc-welding generator with bucking series field and stabilizer in the arc circuit. This resulted in an arc characteristic which made it easy for an ordinary welding operator to learn how to weld. The present price of around $550 for a 400-amp. unit which is better than the early units which sold for $3000 or $4000, is the result of applying technical knowledge to people's manufacturing problems and creating a demand for the equipment.

In the field of electric arc-welding electrodes Mr. Lincoln pioneered in the development and application of shielded arc electrodes. Some ten years ago such electrode was selling for roughly 20¢ per pound. Mr. Lincoln put machinery and equipment into his plant to make it, a research department to improve it, and today the product sells roughly at 5½¢ per pound in carload lots.

In the field of automatic arc-welding equipment, Mr. Lincoln early recognized the coming need for speed and precision. He picked the carbon arc process as one susceptible to development in this direction. For a number of years he spent substantial sums of money developing the equipment with little financial return. He developed mechanism that would hold the arc to a predetermined length; a means of shielding the arc to give weld metal equal to and in many respects better than the steel to be welded; enveloping magnetic fields to stabilize the arc. In spite of administrative duties he went out and engineered the application of the equipment itself.

WANTED

CHIEF ENGINEER FOR RESISTANCE WELDER MANUFACTURER

We are in need of forceful, high caliber man with resistance welding experience. Must have good electrical and designing background and be able to supervise men. This is a once in a life time opportunity for a top flight chief engineer who is full of new and progressive ideas. Our post-war position will be strong as we have no conversion problem and we also have a number of new and unusual engineering developments that will enlarge our marketing possibilities.

ADVANTAGES

Modern air conditioned drafting room, profit sharing plan, good future, excellent salary, with opportunity to become stock holder after ability is proven.

Write us sufficient information so a personal interview can be arranged. Our employees know about this advertisement.

PROGRESSIVE WELDER COMPANY

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Time Counts—
Gas cut and Weld with

Shawinigan Carbide

SHAWINIGAN

FOR VICTORY BUY UNITED STATES WAR SAVINGS BONDS AND STAMPS

SHAWINIGAN PRODUCTS CORPORATION
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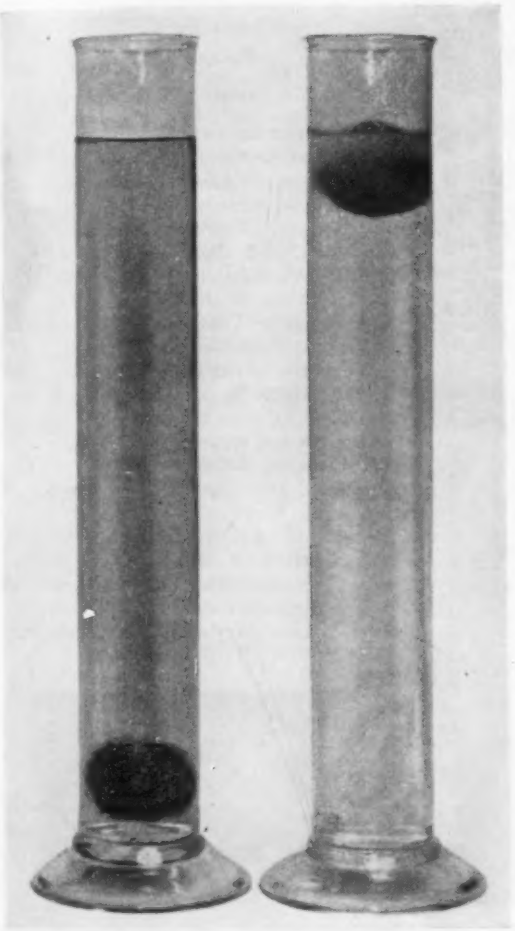
REMOVE SCALE AFTER HEAT TREAT

WITH DIVERSEY EVERITE



Diversey Everite is a powerful solvent specially developed to remove heat scale quickly and completely without harming the sound metal. Will not change dimensions of forgings and castings. Also removes rust from metal surfaces. Reduces hydrogen embrittlement. Economical . . . works only on oxide and other unwanted deposits . . . not on the metal. Easy to use by soak or circulating method. P.S.—Remove quenching oil with Diversey DC-22 in tank cleaning or DC-14 in power washer.

1. REDUCES HYDROGEN EMBRITTLEMENT

Here's proof—Place a small wad of steel wool in graduates filled with Diversey Everite and raw acid. Note how the steel wool is carried to the surface by bubbles of hydrogen released by the raw acid. In the Everite solution, the steel wool remains at the bottom . . . there's no evolution of hydrogen, no corrosion.

2. WILL NOT INJURE METAL SURFACE

Here's proof—Select two rusty pieces of steel. Place one in a solution of Diversey Everite and the other in raw acid. Note how Everite removes the rust quickly and completely, AND THEN STOPS while the raw acid continues to dissolve the sound metal after the rust is gone.

VISIT THE DIVERSEY EXHIBIT
SPACE #A-624
NATIONAL METAL EXPOSITION
Cleveland, Ohio, October 16-20

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The process is today one of the most widely used in welding and is known as the Electronic Tornado.

In the field of induction motors Mr. Lincoln brought about the following developments: use of squirrel cage motors for elevators; application of high-resistance rotor squirrel cage induction motors to flywheel drives; and use of welded steel in induction motor construction.

Mr. Lincoln is the author of: *An Industrialist Looks at 'The New Deal', Tell the Truth and Keep Out of the Way, Ignorance of the Law is no Defense, Who can Employ the Idle?, Intelligent Selfishness and Manufacturing* and many scientific and technical articles and papers.

He is also a well-known lecturer on all phases of welding as well as on economic and political subjects. He has lectured before many audiences the world over.

Mr. Lincoln is widely known for his ability as a manufacturer and for his philosophy on management-worker relationship.

* * *

H. Malcolm Priest

H. Malcolm Priest was graduated in Civil Engineering from Massachusetts Institute of Technology in 1912.

For many years he was with the American Bridge Co., and was assigned to the study and design of welded structures in 1926. He designed some of the earliest welded buildings erected in this country.

Since 1933, he has been Engineer of the Railroad Research Bureau of the U. S. Steel Corp. Subsidiaries.

H. M. Priest

He was Vice-Chairman of the first Structural Steel Welding Committee and has been a member of several other committees of the SOCIETY, also serving as Chairman of the New York Section.

Mr. Priest has contributed papers, from time to time, to THE WELDING JOURNAL and lectured before the SOCIETY and some of its Sections. He was the author of a book on Practical Design of Welded Steel Structures.

DISTRICT VICE-PRESIDENTS

District No. 1

New York and New England—F. C. Fyke

F. C. Fyke, Head, Materials Division, General Engineering Department, Standard Oil Development Co., Elizabeth, N. J., is a graduate of Ohio Northern University with the degree of B.S. in Mechanical Engineering, 1916 (in 1921 he was awarded the degree of M.E. by the University). After

F. C. Fyke

two years of educational work in Minnesota he became associated with the Standard Oil Co., N. J., in 1918 as Test Engineer in the General Engineering Department. When this Department became a part of the Standard Oil Development Company in 1928 Mr. Fyke continued in this work. Since 1931 he has been head of the Materials Division which involves testing and inspection of materials and engineering research.

Being a member of the AMERICAN WELDING SOCIETY for many years he has served on a number of its committees. He was one of the founders of the Northern New Jersey Section and served two years as its Chairman and is now a member of its Executive Committee. He is a member of the Sectional Advisory Committee. He is a member of several committees of A.S.T.M., A.P.I. and other technical organizations.

* * *

District No. 2

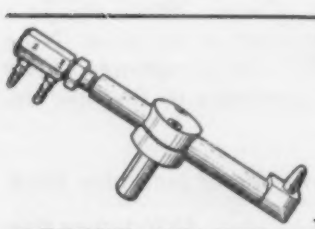
Middle Eastern—H. W. Lawson

H. W. Lawson has been an active member of the AMERICAN WELDING SOCIETY for the past ten years. A member of the Philadelphia Section, until 1943, he served on the local Board as Director, Vice-Chairman, and Chairman. He resigned from the Philadelphia Section to assist in the formation of the Lehigh Valley Section serving as Temporary Chairman and as the first Chairman of the Section.

When the redistricting of the SOCIETY left the Middle Eastern District without a District Vice-President, he was selected by the Section representatives to serve in this capacity, following which, he was nominated and elected to serve again for the current year.

Active in the structural welding field, he has presented papers on this subject before local Sections, and has served on local and national committees of the SOCIETY. As a member of a subcommittee

H. W. Lawson



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Butt
Flash
Spot
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ELECTROLOY

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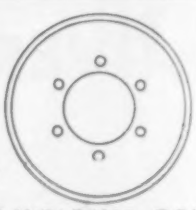
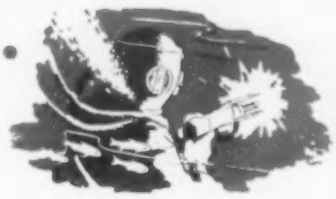


OFFSET HOLDER

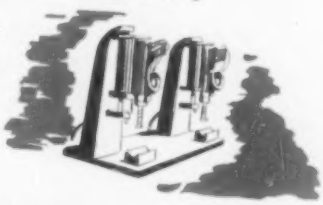
THE ELECTROLOY CO. INC. 1600 SEAVIEW AVE. BRIDGEPORT, CONN. WELDING ROLL

Underwater Welding...



See how the Nelson Stud Welder is used for salvage work. Welding studs with gun submerged in salt water.

Multi-gun Production Unit...

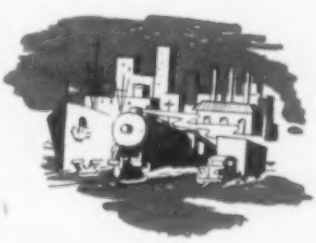


The latest developments for production-line stud welding. Completely automatic units demonstrated.

New DC "Model J" Stud Welder...

Operates solely on DC current and requires only one cable. It's the answer to many industrial production problems.

New Applications...



How stud welders are used on electrical transformers and equipment; boiler tubes; locomotive cabs; freight cars; securing metal lath and plaster; and heavy machinery manufacture, etc.

PLUS THESE FEATURES...

- Make perfect welds *yourself* in less than ½ second!
- See cutaway views of many kinds and sizes of studs!
- See samples of all the uses developed to date for Nelson "Flux-filled" Studs.
- Free samples of stud welding!

NELSON STUD WELDERS & STUDS

—USED BY MORE THAN 460 INDUSTRIAL PLANTS AND SHIPYARDS!

on structural welding research his greatest interest has been in developing rational design methods for and standardization of welded structural details. He is also a member of the American Institute of Steel Construction Committee on Steel Structures Research.

He is employed by Bethlehem Steel Co. as an Engineer in the Fabricated Steel Construction Division, specializing in welded steel structures, having come to Bethlehem from Levering and Garrigues Co., New York, when that company was acquired in 1931.

Holding the degree of Civil Engineer, he is a member of the American Society of Civil Engineers and is a Licensed Professional Engineer.

District No. 3

Southern—F. E. McAtee

F. E. McAtee was born at Barry, Ill., on April 7, 1905, and received his elementary education there. He spent two and one-half years as Junior Highway Engineer for the Illinois Division of Highways between his junior and senior years at the University of Illinois, whence he graduated in 1930 with the degree of B.S. in C.E. with high honors.

Immediately after graduation, he joined the Chicago Bridge & Iron Co. and worked in an erection crew in Borger, Texas, until May 1931, when he was sent to the newly acquired Birmingham plant. He learned to arc weld with bare rod in the field, and in the spring of 1932 spent six weeks at the

F. E. McAtee

Lincoln Welding School at Cleveland studying coated electrode welding.

Since then he has worked in the Birmingham shop as a welder, welding foreman, welding engineer and assistant superintendent. He has also served as consultant on special welding problems throughout the organization.

Mr. McAtee helped organize the Birmingham Section of the AMERICAN WELDING SOCIETY in 1937 and has been active in its affairs since, serving as chairman in 1941. He is a member of Chi Epsilon, American Society of Metals, AMERICAN WELDING SOCIETY and Birmingham Engineer's Club.

District No. 4

Central—J. F. Maine

J. F. Maine was born at Kenton, Ohio, on Dec. 7, 1888. After graduating from high school at Cleveland, he entered the Engineering Department of Variety Iron and Steel Co. His education was continued by attending night classes at various schools and colleges.

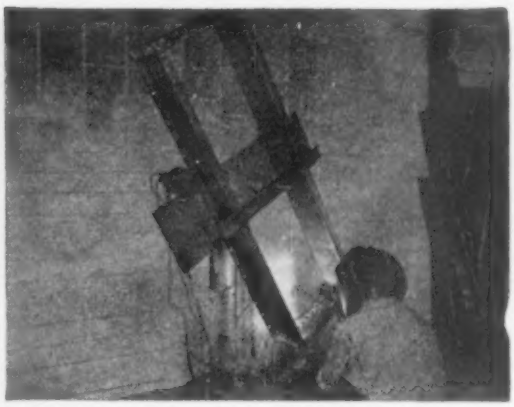
J. F. Maine

"YOU See THE CHARGE"
"Welcome Always"
● Equally at home in small shop or large factory, Sight Feed owes its nation-wide acceptance to the following versatility of performance:
1 Sight Feed generates purer, hotter acetylene gas at savings to you of 50% to 75%.
2 Sight Feed furnishes all the acetylene you want when you want it. No delivery delays from bottlers.
3 Sight Feed avoids large-job interruptions . . . thanks to its fool-proof, visible carbide supply.

THE *Sight Feed* GENERATOR COMPANY • SALES: RICHMOND, IND. • FACTORY: W. ALEXANDRIA, O.

It has always been the policy of the Metal & Thermit Corporation to pay special attention to the development of electrodes for welding special steels. Murex Carbon Moly. 50, Molex and Type M, for example, are outstanding in their performance for welding carbon-molybdenum steel plate, castings, high pressure, high temperature piping and pressure vessels. Murex R.C. and C.F., for the repair and welding of air-hardening steel castings are among the electrodes developed to meet the needs of war production.

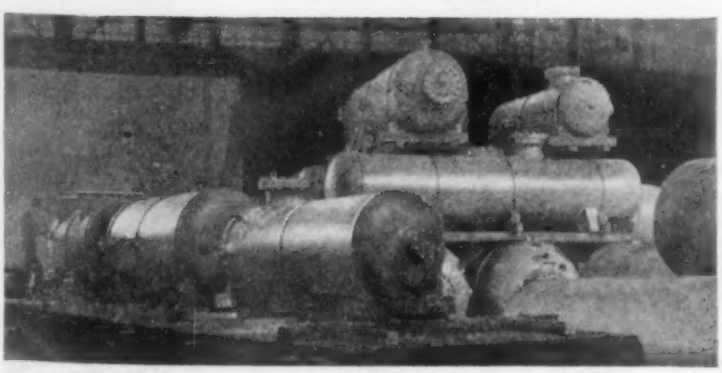
As the electrode requirements of fabricators change with the advent of industrial conversion, suitable Murex Electrodes will be available.



PROVIDING HEAT AND FRESH AIR FOR OUR COMBAT VESSELS, these heating units, produced by McQuay, Inc. of Minneapolis, must be rugged to withstand gunfire shock and near miss bomb concussion. To combine sturdy construction with light weight, welded construction using Murex Electrodes was adopted for the heater casings.

HUGE TURBINES FABRICATED WITH MUREX ELECTRODES by S. Morgan Smith Company, world's largest exclusive turbine builder. The illustration shows welding of a three-way branch inlet of a Vertical Impulse Turbine. Advantages of arc welding are: elimination of possible defects of complicated castings; less metal used; figuring of exact weights possible, thus enabling manufacturer to keep within estimates. Down-hand Murex Electrodes are used.

THIS 7½-TON STEEL CYLINDER on an 800-ton hydraulic press developed a crack 20 inches long and after preparation for welding 3 inches wide, and from 4½ to 6½ inches deep. Preheated 9 hours at about 700° F., this temperature was maintained during 17 hours of continuous welding with Murex Type F ¼ inch rods. The Detroit & Cincinnati Welding Company report that cylinder wall distortion was only about .0015" and that the flange moved only .004".



PRESSURE TANKS FOR HIGH OCTANE GAS, produced in quantity by The Bigelow Company of New Haven, Connecticut, are welded with low alloy Murex Electrodes to withstand pressures of from 100 to 600 pounds.

MUREX

ARC WELDING ELECTRODES

•

METAL & THERMIT CORPORATION

120 Broadway, New York 5, N. Y.

ALBANY • CHICAGO • PITTSBURGH
SOUTH SAN FRANCISCO • TORONTO

Specialists in welding for nearly forty years. Manufacturers of Murex Electrodes for arc welding, and of Thermit for repair and fabrication of heavy parts.

He entered the employ of Republic Structural Iron Works in June 1909 as a draftsman in the Engineering Department. For the past 21 years, he has been Chief Engineer of this Company and its affiliates.

Mr. Maine has been Chairman of the Cleveland Section, A.W.S., serving two years. He was also first Chairman of the Symposium Committee. At various times he has been Chairman of Educational, Building Code, and Membership Committees.

He is a Registered Professional Engineer in the State of Ohio.

District No. 5

Middle Western—Walter J. Brooking

Mr. Brooking was born in Montana and worked for varying intervals in heavy construction work, lumbering and sawmill operation in the northwestern states prior to graduating from Whitman College, Walla Walla, Wash., 1934.

In the fall of 1935, Mr. Brooking joined the organization of R. G. LeTourneau, Inc. at Peoria, Ill.; served for over a year as Transportation Supervisor; was graduated from the University of Chicago in May 1937, and returned to R. G. LeTourneau, Inc., immediately after graduation to the Time Study Department where he made time studies and set time study standards for the arc welding of large earth-moving equipment structures.

In 1938, Mr. Brooking was transferred

W. J. Brooking

to the Engineering Department to establish the control of arc welding by symbols on shop blueprints and to organize methods for the elimination of lost efficiency due to poor fit-ups and other control elements of welding; was appointed Director of the Chemical Laboratory and Director of Plant Education in 1940 and Director of Testing and Research in 1942. He is the author of numerous technical articles, the majority of them dealing with welding and its control, although several covered various aspects of plant education and technical control in industry.

Mr. Brooking was one of the charter members of the Peoria section of the AMERICAN WELDING SOCIETY; served twice as its chairman and has been an active participant and speaker on numerous A.W.S. sectional programs dealing with arc-welding control as applied in the manufacture of heavy earth-moving equipment.

McGraw-Hill Book Co., Inc., is at present producing a book under his authorship, *Arc Welding, Engineering and Production Control* which should probably be out of the press some time this fall. An important part of one chapter of this book is devoted to the A.W.S. and its services and activities as related to the student of welding problems or the organization producing welded goods.

District No. 6

Mid-Southern—M. A. Barrett

M. A. Barrett is responsible for the upkeep and repair of something in the neighborhood of $3,000,000 worth of machinery and equipment at Beech Aircraft Corp., Wichita, Kan. This, coupled with the fact that Beech has never had a major shutdown, begins to portray the man Barrett. Typical of the jobs handled by the men under his supervision is the repair of an "unrepairable" part of a 2500-ton Hydro-Press in less than 30 days at a cost of

FREE

ENGINEERING INFORMATION *for* BETTER WELDING

This New Engineering Bulletin contains important technical information that may save you time, labor and money on many welding jobs. Learn how to keep welding jigs free of spatter; how to save mill-scale cleaning time after normalizing; how to reduce fumes; etc. etc. Contains actual case histories and laboratory authenticated reports. Write for your copy now.

WELDING SUPPLY DISTRIBUTORS AND SALESMEN WANTED

The MIDLAND PAINT & VARNISH CO.

9126 RENO AVENUE CLEVELAND 5, OHIO

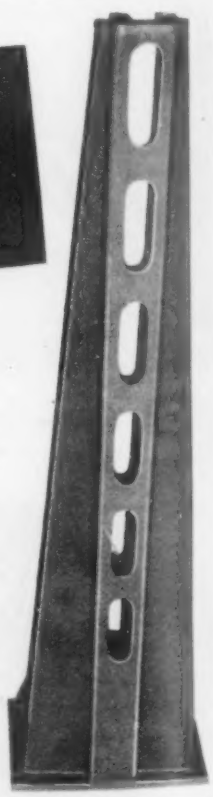
RARELY TOO LARGE AND NEVER TOO COMPLICATED TO BE WELDED SUCCESSFULLY

Thirty-one years of growth in equipment and welding skills fully warrant that statement . . . "rarely too large and never too complicated".

United Welding therefore invites you to submit your drawings for quotation . . . though the weldment desired be large or small, light or heavy, simple or involving special problems.

The former arm here shown, a typical weldment, measured 12 feet overall and weighed 1900 pounds.

How about that post-war unit? May we study the drawings—in confidence—and quote you on the parts that could be of welded construction?



ARMY E NAVY

WELDING ENGINEERS UWCO MIDDLETOWN, OHIO

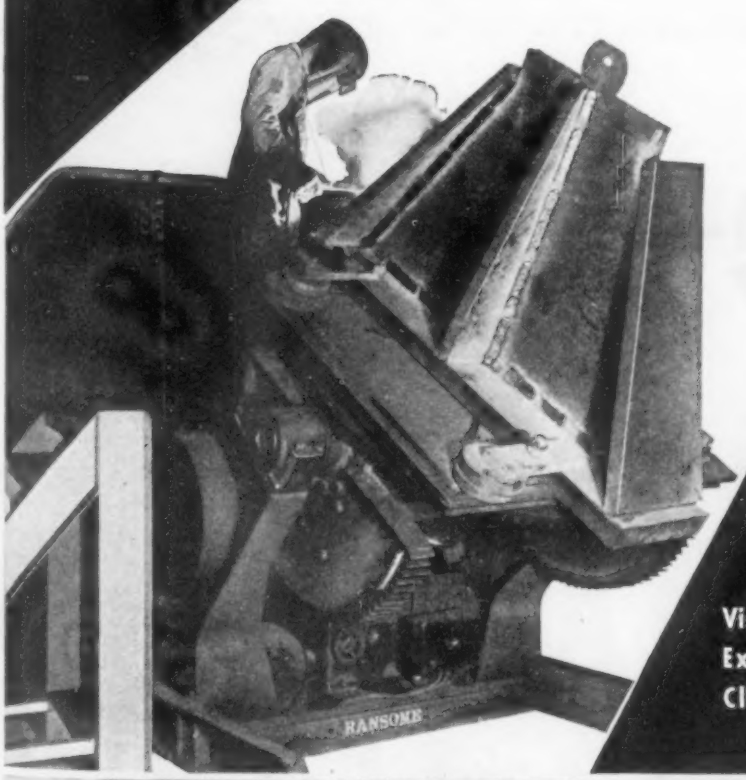
THE UNITED WELDING CO.
MIDDLETOWN, OHIO
WELDING FABRICATORS OF MODERN DESIGNS

HOW TO CUT POSTWAR PRODUCTION COSTS

Ransome Welding Positioning Equipment provides one way to improve the quality of your postwar product and to substantially cut costs... simultaneously.

Postwar competition spotlights production costs. With welded construction so much a part of postwar industrial design, it will pay you to investigate the cost-cutting, production-boosting advantages of this equipment.

Write or phone your nearest Ransome distributor or write us direct for complete information.



SAVE up to 50% welding costs.

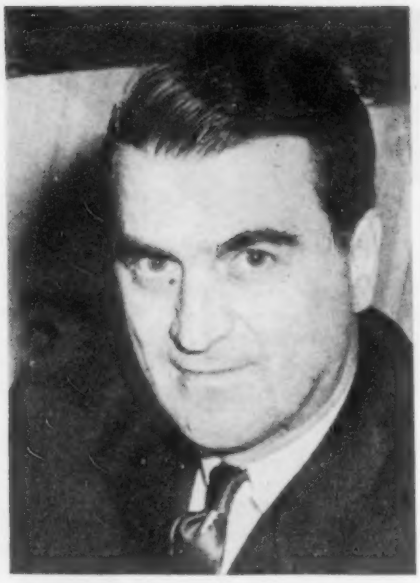
REDUCE accident hazards and crane service.

PRODUCE better, stronger and smoother welds.

INCREASE welding production up to 50%.

Visit our exhibit booth B-102, National Metals Exposition, Cleveland Public Auditorium, Cleveland, Ohio, October 16th thru 20th.

INDUSTRIAL DIVISION **Ransome MACHINERY COMPANY**
DUNELLEN, NEW JERSEY
SUBSIDIARY OF WORTHINGTON PUMP AND MACHINERY CORPORATION



M. A. Barrett

approximately $3000. To have replaced the part would have entailed an initial cost of $20,000 and a loss of from three to six months at an hourly rate of $125. Mr. Barrett has had a great many titles, but by far the best known, and his favorite, is just "Mickey."

Mickey started training for a career as welding engineer, just out of high school, with the old Standard Parts Co. of Cleveland, Ohio, in 1917. In 1921, he became associated with Air Reduction Sales. As A. E. D. Engineer and Sales Engineer, Mickey and his career progressed in the ensuing years to such an extent that in 1934 he left Air Reduction Sales and "Welding Engineer Barrett" started out on his own, contacting oil fields.

The oil-field phase of Mickey's welding activity was cut short to accept an appointment as assistant supervisor of correspondence studies in the Extension Division of the University of Oklahoma.

Mickey has built an enviable reputation as Beech Aircraft Corp. in the past four and a half years. There are very few departments in the plant that have not felt the Barrett "get the job done" technique—and liked it.

In addition to Mickey's present post as District Vice-President, he is a member of the Membership Committee of the national and also local chapters, AMERICAN WELDING SOCIETY, member A.S.M., member A.S.T.E.

F. A. Longo

District No. 7

Western—F. A. Longo

Frank A. Longo was born April 14, 1897, in Los Angeles, Calif. He entered railway service on July 1, 1913, as Boiler Maker Apprentice for the Southern Pacific R.R. He attended Polytechnic Evening High School, graduating in 1917.

After finishing his apprenticeship he served as Boiler Maker, Layer-Out, Welder and Boiler Inspector, until 1921 when he was promoted to Boiler Foreman. In 1928 was advanced to Boiler and Welding Supervisor of the Los Angeles General Shops. Finished course in Mechanical Engineering with the International Correspondence Schools.

In 1939 was advanced to General Boiler Foreman, Bayshore Shops, San Francisco. In June 1941 was promoted to General Boiler Inspector, in charge of Boilers Welding and Cutting in Motive Power Department.

Two years of his career were spent inspecting new Southern Pacific locomotives at the factory.

National

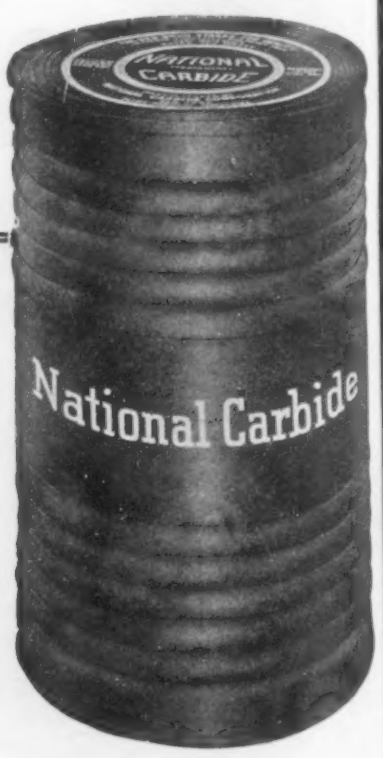
Carbide

IN THE RED DRUM

EFFICIENT

ECONOMICAL

DEPENDABLE



FOR WELDING and CUTTING

Use National Carbide in the Red Drum

60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York, N. Y.

Coming October 16

A 72-HOUR, FIVE-DAY WEEK FOR THE METAL INDUSTRY

DEVOTED TO THE STUDY AND FUTURE APPLICATION OF WAR DEVELOPMENTS IN METALS • • • •

An interest-packed, 72-hour week is in store for the metal industry during the 26th annual National Metal Congress and War Conference Display, the week of October 16 in Cleveland's Public Hall.

Meeting to summarize the new developments and processes of the war years, to take stock of their value for tomorrow's applications, the metal industry will take part in a series of practical panel-type sessions each afternoon and evening. Nearly 300 experts representing the major branches of the industry will actively participate in these panel sessions.

At 9:30 each morning and running afternoons and evenings, more than 150 research developments in the metal industry will be presented under the auspices of five national technical societies. More than a thousand metal men have prepared these fast-moving technical papers.

Opening at noon each day and continuing through the evening, more than 300 conference displays, manned by the executive and engineering experts of industry's leading manufacturers, will explain and demonstrate developments in products, processes and equipment and point out their application in the Design for Tomorrow.

All-in-all, it will be a full 72-hour, five-day week of work and learning for the thousands who will attend. Plan to be there — make your hotel reservations now through the Housing Bureau, Cleveland Convention and Visitors Board, 1604 Terminal Tower, Cleveland 13, Ohio.

NOTE — While more than 300 manufacturers have taken display space, a few choice locations are still available. For details, write or wire collect to the American Society for Metals, 7301 Euclid Avenue, Cleveland 3, Ohio.

CLEVELAND'S *Public Hall*

NATIONAL METAL CONGRESS

OCTOBER 16 THRU 20, 1944.

AND WAR CONFERENCE DISPLAY

Sponsored by the American Society for Metals, in cooperation with the American Welding Society, the Iron and Steel and Institute of Metals divisions of the American Institute of Mining and Metallurgical Engineers, the American Industrial Radium and X-Ray Society and the Society for Experimental Stress Analysis.

He was Chairman of the Los Angeles Section of the AMERICAN WELDING SOCIETY in 1934, and of the San Francisco Section in 1942 and 1943.

At the present time he is Vice-President of the Master Boiler Makers' Association and Chairman of the Executive Board

SUSTAINING COMPANY

The Chapman Valve Co. was organized in the early '70's and constructed a plant in Indian Orchard, Mass., a suburb of the City of Springfield.

It is a self-contained unit having its own iron, bronze and steel foundaries with complete machining equipment for the manufacture of gate and globe valves in iron, steel, bronze and alloys of various types and in sizes up to 84 in.

It also manufactures sluice gates and many other types of valves devoted exclusively to sewage disposal and water supply.

SUSTAINING MEMBER

Sciaky Bros., Chicago, manufacture a complete line of electric resistance welding equipment. The organization has pioneered and developed many of the recent improvements in this type of welding—the welding of aluminum with Stored Energy, automatic forging of the weld, machines for steel operating on three phase with a perfectly balanced load, etc. Equipment includes press, rocker arm, seam, portable, projection, butt and flash welders, and various electronic and pneumatic controls for welding processes.

METALS SOCIETY TO RECEIVE ORDNANCE AWARD

The American Society for Metals will receive the Ordnance Distinguished Service Award in recognition of its contributions to the war effort, according to word received August 28th by W. H. Eisenman, national secretary of the Society, from Major General L. H. Campbell, Jr., Chief of Ordnance.

The award recognizes the Society's over-all efforts to speed war production through metals education and training work. Especially noted were A.S.M.'s courses for the training of inspectors and its publication at cost of the textbook, *Inspection of Metals*.

WELDING DISTRIBUTORS ASSOCIATION

The Welding Distributors Association will hold its Second Annual Meeting in Cleveland this year. With the idea of giving the members an opportunity to attend any of the sessions planned in connection with the Metal Show, in which they might have an interest, the dates of October 14th, 15th and 16th were chosen. Mr. C. I. MacGuffie, Manager of the Electric Welding Division of the General Electric Co., with others of his staff, will be on hand to help with the solution of production and distribution problems. Invitations have been sent to eligible distributors, who are not members of the Association, and many of them are expected to attend.

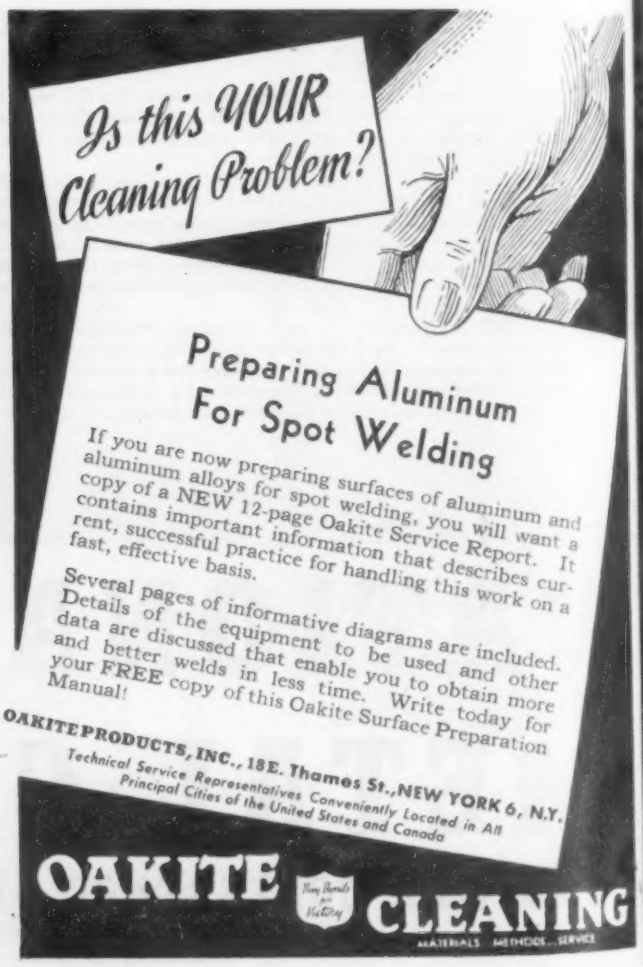
RESISTANCE WELDING UNITS FROM THE CONSUMER'S POINT OF VIEW

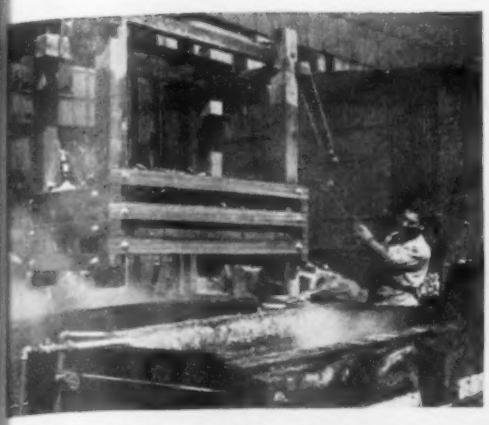
At a recent meeting of the Resistance Welder Manufacturers Association, Mr. John Diebold, welding engineer for General Motors Truck and Coach Division, gave an interesting discussion on just what the user would like to have in resistance welding equipment.

"The resistance welding industry has done an excellent job," commended Mr. Diebold. "Your equipment is good, in fact better than the material used. The next important step is that of bringing the metallurgy of these materials up to par."

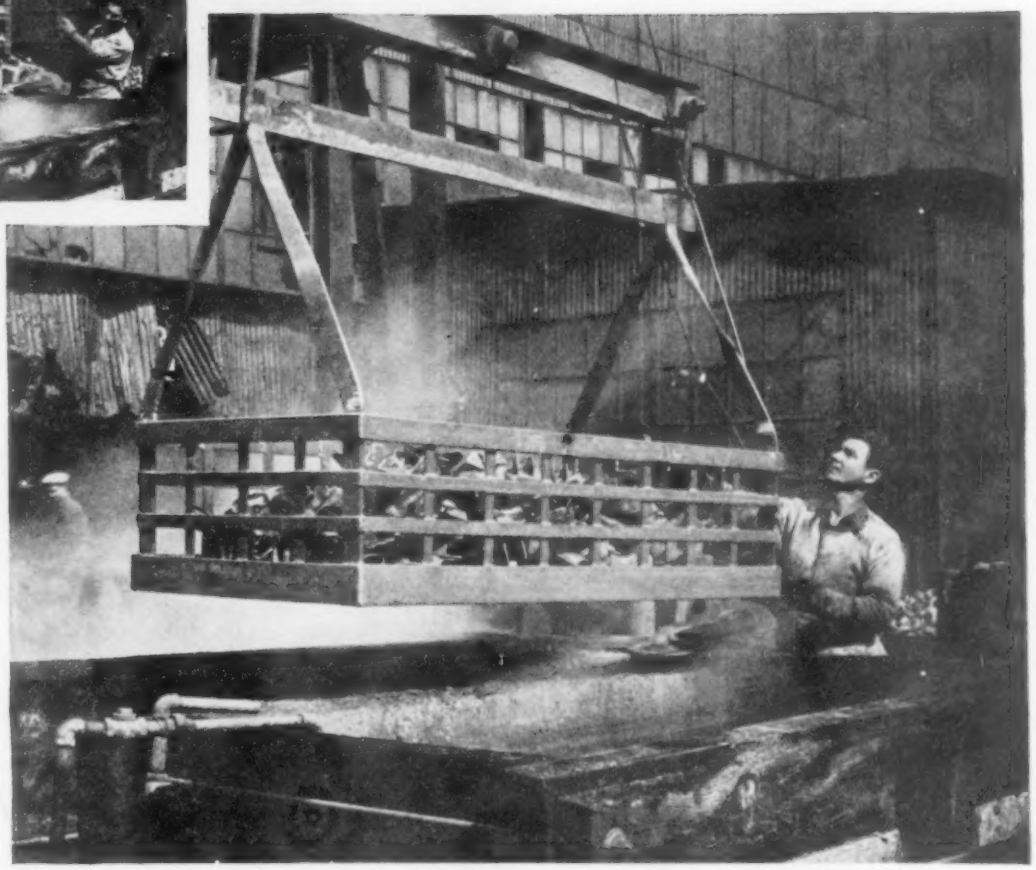
Need for standardization was stressed, not only in the complete units, but in small parts and fittings as well. As an example, Mr. Diebold mentioned the automobile industry in which parts, such as tires, batteries, spark plugs, headlights, bumper heights and many other parts, are standard on all makes. This interchangeability makes for a cheaper, more flexible use of the equipment, and makes it unnecessary for the user of resistance welding equipment to carry a large inventory of special parts for each type of machine. This

Reach for
DUCTONE
(E6011) AC (E6013)
WELDING RODS
Available again, after three years of war service. DUCTONE AC rods are designed and manufactured especially for AC welding. It is the best rod for all position and general purpose welding. DUCTONE AC rods have deep penetration, are good on dirty materials and operate on exceptionally low current. Small sizes are especially good for thin sheet metal. Excellent for vertical and overhead welding on DC positive polarity. Extruded in all sizes from 1/16" to 1/4". See your dealer.
Territories Available for Distributors
DUCTONE AC ELECTRODES
Chicago Steel and Wire Co.
103rd St. and Torrence Ave.
Chicago 17, Illinois
Reach for DUCTONE AC Welding Rods


Is this YOUR Cleaning Problem?
Preparing Aluminum For Spot Welding
If you are now preparing surfaces of aluminum and aluminum alloys for spot welding, you will want a copy of a NEW 12-page Oakite Service Report. It contains important information that describes current, successful practice for handling this work on a fast, effective basis.
Several pages of informative diagrams are included. Details of the equipment to be used and other data are discussed that enable you to obtain more and better welds in less time. Write today for your FREE copy of this Oakite Surface Preparation Manual!
OAKITE PRODUCTS, INC., 18E. Thames St., NEW YORK 6, N.Y.
Technical Service Representatives Conveniently Located in All Principal Cities of the United States and Canada
OAKITE CLEANING
MATERIALS METHODS SERVICE



THE WOODEN PICKLING BASKET *(above) carried only* half *the volume of the strong, corrosion-resistant welded Monel basket (right). Product of the Youngstown Welding & Engineering Co., the Monel basket is electric arc-welded with* INCO *130X Monel electrodes . . . handles 4,000 lbs. at a time.*



PICKLING TANK CAPACITY DOUBLED

...Welded Monel basket carries TWICE the former crate load!

The simple, effective way in which a welded Monel basket raised pickling capacity is illustrated above.

The small photo shows the tank with the former pickling crate, made of wood, used by the Pittsburgh Forgings Co., Pittsburgh, Pa.

The large picture shows a welded Monel basket, designed and built by the Youngstown Welding & Engineering Co., in use with the same tank.

Outside dimensions of the crate and basket are practically the same. Yet the welded Monel basket carries just about *twice* the bulk load!

In service, the Monel basket has also proved to be a time and trouble saver. Electrically arc-welded with INCO's No. 130X electrodes, the basket has firm, strong welds that resist the severe corrosive attack of hot pickling acids as effectively as do the Monel flats. And tough Monel takes in stride the bumps and jolts it gets in handling 4000 lb. loads.

It is an excellent example of the superior service that can be obtained with an all-Monel job... Monel sheet, bar or rod, welded with Monel electrodes.

INCO NICKEL ALLOYS

MONEL • "K" MONEL • "S" MONEL • "R" MONEL
"KR" MONEL • INCONEL • "Z" NICKEL • NICKEL
Sheet...Strip...Rod...Tubing...Wire...Castings

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street **New York 5, N. Y.**

could be done, as it has been done in the automobile industry, without sacrificing individuality.

Such standardization is the keynote to the ultimate universal acceptance of resistance welding by the manufacturer of metal products.

"The small fabricating shop," Mr. Diebold stated, "should be made resistance welding conscious. They are not aware of the great savings in time and cost possible through resistance welding."

Mr. Diebold made this important comment in closing: "Resistance welding is the cheapest, quickest, most foolproof joining method known. It could and should command every metal fabricating problem with the exception of very heavy, remote field work."

BOOKLET ON UNDERWATER CUTTING AND WELDING

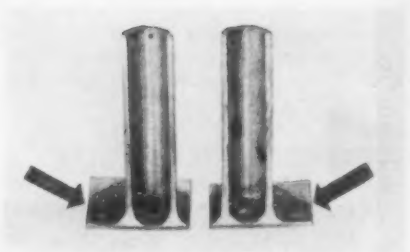
Because of the wide interest in an article on "Underwater Cutting and Welding" written by H. L. Ingram, Jr., of the Applied Engineering Department of Air Reduction Sales Co., the article has been reprinted in booklet form.

Opening with a brief story of the history of the processes, the author goes on to describe the techniques used for both torch and carbon arc cutting and metallic arc welding underwater and lists pressure tables for torch cutting at various depths and tip sizes for cutting materials from ¼ to 2 in. thick.

Copies of the booklet may be obtained from the general offices of Air Reduction, 60 East 42nd St., New York 17, N. Y., or from any of the company's sales offices located in principal cities.

FREE FLOWING SOLDER FOR ALUMINUM

Sheet aluminum can now be lock seamed, or lapped and spot welded or riveted, and the joint sealed with a new free-flowing solder, EutecRod 199, just developed by the manufacturers of Eutectic "Low Temperature" Rods. This improved rod supplants the alloy previously known as EutecRod 19B. This is the first free-flowing soft solder, for use on aluminum and aluminum alloys. Used with Autochemic Eutector Flux 199, EutecRod 199 will flow on aluminum as readily as ordinary lead-tin solder on tin-plate, brass or copper.



Photograph Illustrates the Free-flowing Property of EutecRod 199. Note the smooth Full Fillets That Are Formed Between the Tube and the Sheet

EutecRod 199 is used on aluminum like the old lead-tin solders would be used on tin-plate or brass and copper. In long laps it will make joints of moderate strength, but it should generally be used as a seal. This rod will work on cast aluminum as well as on wrought aluminum, and on steel, copper and nickel alloys. EutecRod 199 is suitable for applications where the completed joint will not be heated over the boiling point of water (212° F.) under working conditions. Its "Low Temperature" of application, 400° F., makes it possible to join thin sheet metal without danger of distortion. EutecRod 199 will even bond to cast iron, if the iron has first been "tinned" with a zinc-base solder.

G. A. OSTROM MOVES TO FOOTE MINERAL

Foote Mineral Co., Philadelphia, announces the retention of Gustuf A. Ostrom as a Research Engineer. Mr. Ostrom, a graduate of Girard College, Philadelphia, and a Certified Physical Metallurgist, comes to his new post after four years as a radio technician with Philco Radio Corp., and six years' research and development work with Arcos Corp. on stainless steel and alloy welding electrode coatings and weld deposits, metallurgical control of raw materials and finished products. Mr. Ostrom has also taught metallurgical laboratory practice at Temple University Evening School.

THE CHAMPION RIVET COMPANY APPOINTS N. J. CARBIS

The Champion Rivet Co., Cleveland, announces the appointment of N. J. (Jack) Carbis as Special Railroad Representative.

Mr. Carbis has had 30 years' experience in the railroad field, part of which time was spent as general boiler foreman, for the B. & O. R. R.

He will concentrate on the sale of Champion welding electrodes and accessories to the railroads, steel car and locomotive builders throughout the United States.

The company realize that the application of welding presents many technical problems to the railroads, and accordingly have set up a special railroad department to handle the sales and service of their welding electrodes which product they have been manufacturing since 1931.

Mr. Carbis, who was born in Pittsburgh, Pa., attended Carnegie Institute of Technology and is a member of the AMERICAN WELDING SOCIETY and the Master Railroad Boiler Makers Association.

PRESSURE SHOCK EQUALIZING VALVE

"Chek-Shock" pressure shock equalizing valve for use with high-pressure gas regulators employed in connection with oxyacetylene welding and cutting equipment. Device acts to eliminate sudden

Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them

The Trade-Name is "ANTI-BORAX"

Ask for Them ***Unequalled for Quality***

A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Braz-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; No. 16 Silver Solder Paste Flux.

ANTI-BORAX COMPOUND COMPANY

Fort Wayne, Indiana

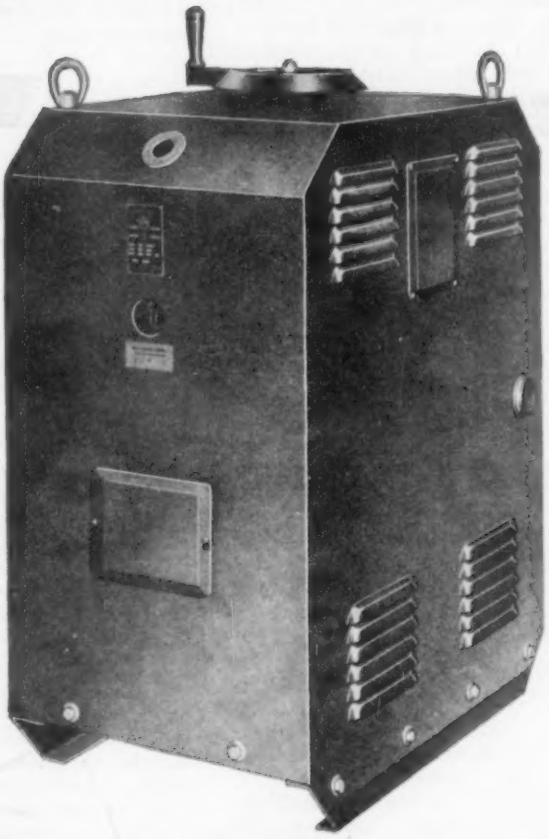
NET MONTHLY ADVERTISING RATES

Black and White *Effective April 1943*

Space	One Insertion	Three Insertions	Six Insertions	Twelve Insertions
*Full Page	$120	$105	$95	$85
Half Page	70	60	55	50
Quarter Page	42	38	35	30
Eighth Page	30	25	20	18
*Inside Preferred	135	120	110	100

*10% Extra for bleed full pages. Color $40 Extra per color added.

YOUR POSTWAR WELDER



IS READY *Now!*

G-R, the welder that set the pace in the wartime swing toward a.c. welding's speed and economy, is ready *now* with job-tested features that will save you time and money on tomorrow's competitive job of winning the peace.

G-R Volt-O-Matic control, reducing open circuit voltage to less than 10 volts, is available for all models and is standard equipment on Models 39 and 49.

G-R Power Factor Correction, permitting smaller power wiring and reducing power costs wherever low power factor penalties are imposed, is standard equipment on all "C" and Industrial models.

Every G-R unit delivers a *full* welding range—from 15 amperes or less to the top capacity of each model—with ideal all-position welding characteristics at every point in the range.

There's a size to fit every requirement, from the 10-100 ampere Model 10 (drawing less than 30 amperes on a 110-volt line at top output), to the giant 2,700-ampere Model 85.

For better welding at lower cost, for safety unequalled by any other a.c. machine, plan *now* to make G-R *your* postwar welder . . . you'll be hours and dollars ahead!

Get the facts from your nearby G-R distributor, or write to:

GLENN-ROBERTS COMPANY
3100 EAST TENTH STREET · OAKLAND 1, CALIFORNIA
2107 ADAMS STREET · INDIANAPOLIS 1, INDIANA

Remember

G-R WELDERS

admission of full cylinder pressure to regulator upon sudden opening of cylinder valve.

For information address Safety Shock Mfg. Co., Mfr., P. O. Box X, Fowler, Calif.

WARTIME "DOUBLE RING" CEREMONY

It's a case of "to have and to hold" in this "double ring" ceremony at the East Pittsburgh Works of the Westinghouse Electric and Manufacturing Co. The upright ring is having an arc-welding treatment to join its ends in a perfect circle—

while a similar ring, atop still other rings, serves as a means of holding the welded object in proper position for the welder. The rings are rims for war-vital 500-hp. motors.

TRACTOR REPAIRS

Worn grousers on tractor-shoes cause a great loss in traction efficiency. The tracks slip and slide over the terrain with the resultant loss of traction, causing fewer and smaller loads to be had per day—less work accomplished at increased cost of handling—besides delay and loss of valuable time on other equipment on the job.

New parts are difficult to obtain, and then only after considerable delay. This replacement cost may be eliminated by a simple repair method, commonly referred to as "re-treading" the old grouser-shoe, quickly and economically without having to tear down the assembly.

Bulldog tractor grip-lugs are easily attached to the worn grouser-shoe by welding on either of the two sizes available. Its exclusive and specially designed groove and bevel permit the weld to grip the retread material more firmly than other shapes. Made of a special work hardening steel, it becomes harder and tougher with use and in most cases they have been known to outwear the original grouser on the shoe.

For details address Allied Steel Products Inc., N.B.C. Building, Cleveland, Ohio.

BATTELLE TO RECEIVE DISTINGUISHED ORDNANCE AWARD

For outstanding contributions to ordnance progress during the course of the war, the War Department has granted the Ordnance Distinguished Service Award to Battelle Institute, Columbus, Ohio, research organization.

Word of the recognition was received from Major L. H. Campbell, Jr., Chief of Ordnance, who wrote Battelle Director Clyde Williams:

"It is my pleasure as Chief of Ordnance of the Army to tell you on behalf of the Ordnance Department that I am most grateful for the outstanding contributions the Battelle Memorial Institute has made to Ordnance progress in this war. The degree of that progress is best shown by the success of our fighting forces in all theaters of operations.

"To attest the appreciation of the Department for the splendid services of your Institute, I wish to present to the Institute the Ordnance Distinguished Service Award. It is a diploma bearing the traditional seal of the Department and is awarded in recognition of scientific and engineering achievement.

Battelle Institute has been actively engaged in research for the Army and Navy and other governmental war agencies since the early days of the war, according to Director Williams. It has conducted research for the Ordnance Department, the Bureau of Ships, the Army Air Corps, the Watertown Arsenal, the War Production Board, the Defense Plant Corporation, the Office of Scientific Research and Development, the National Defense Research Committee, the National Academy of Sciences, and others. Numerous reports on scientific developments have been issued to military and other governmental authorities, and Battelle developments have been incorporated into the machines and production processes of war.

REBUILDING WORN VALVES

"How to Rebuild Worn Valves by Hardfacing" is the title of a recently announced 12-page book of special interest to fleet operators and others whose maintenance problems have been aggravated by inability to secure replacement valves for internal combustion engines.

The book groups worn valves into three groups: those not badly burned or guttered; those which have the faces too badly guttered, pounded or burned to permit reclamation by grinding; and those which have deeply burned areas, gutters and cracks. Most of the text of the book deals with reclamation of the latter two groups, which ordinarily would be replaced, by building up the worn faces and other areas with special hardfacing material applied by means of oxyacetylene torch.

Complete instructions are given for cleaning and inspection of the valves for cracks, preparation for hardfacing, application of the hardfacing metal and finishing. Illustrations show the best methods of performing the various operations.

The book was published by Air Reduction, 60 East 42nd St., New York 17, N. Y. Copies may be obtained by writing that address or from Air Reduction sales offices located throughout the country or local ODT offices which are cooperating in its distribution.

EXTENDING THE LIFE OF TOOLS AND GAGES

An interesting article on the design, maintenance and repair of tools and gages has been written by Frederick L. Woodcock, Chief Engineer, Hamilton Standard Propellers Div., United Aircraft, East Hartford, Conn.

Tools and gages like all other manufacturing equipment and supplies, wear out and break. But a broken tool or gage is a very serious matter because of its cost and, today, the time required for replacement. Fortunately, many broken or worn-out tools and gages can be reconditioned and restored to full usefulness and extended life in service.

It has been found from long experience that the simplest, least expensive and most satisfactory method of repairing broken and worn-out tools is by brazing, and that the outstanding brazing medium in use at present is the low-temperature silver brazing alloy. This alloy has a working temperature of 1175° F., permitting a short heating time and consequently causing a minimum of distortion and reduction in the hardness of the tool. The alloy is free flowing, and capillary action carries it into every part of a joint area. Minimum joint clearances are the best; the thinner the film, the stronger the joint.

The broken tool is set in a fixture devised to suit the job. Cleaning may be done mechanically by abrasives or chemically, with carbon tetrachloride, for example. Proper fluxing keeps the brazed area clean, dissolves the oxides, reduces the surface tension of the silver brazing alloy and makes it free flowing so that it may penetrate to all parts of the joint. The silver brazing alloy may be applied by hand feeding the alloyed wire, by preplacing sheet or strip of the alloy between the parts to be brazed or by pretinning the joint surfaces with the silver alloy.

The heating may be done with the oxyacetylene gas torch, in the muffle furnace, dipping in a molten salt bath or in the induction furnace.

By these methods all types of tools may be repaired: band saws, drills, taps, broaches, milling cutters, forming tools, metal splitting saws, gages, reamers, shanks and tangs of drills and adapters, etc.

Copies of this article may be obtained on request from Handy & Harman, 82 Fulton St., New York 7.

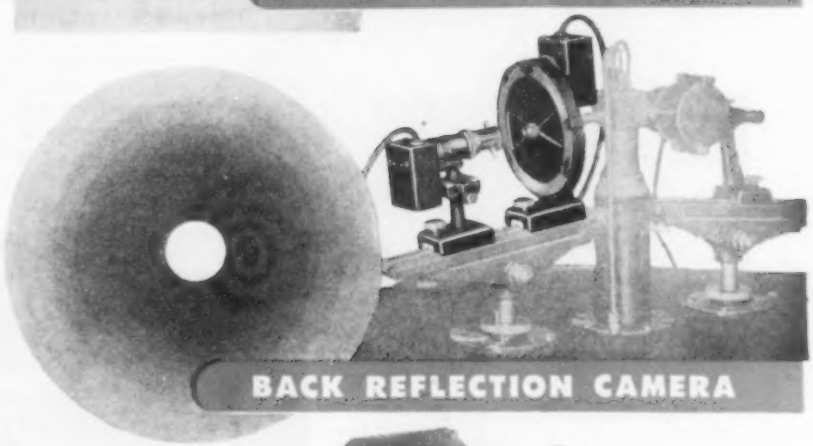
The Laue Camera is used for the observation of preferred orientation of grains or fiber textures and the study of cold work and recrystallization.

Typical Laue Camera Diffraction Pattern; shows preferred orientation.

LAUE CAMERA

The Back Reflection Camera is used for precise measurement of lattice constants, measurement of surface stresses, observation of distortion in crystals and the determination of composition of solid solution alloys. Sample and film may be rotated by motor.

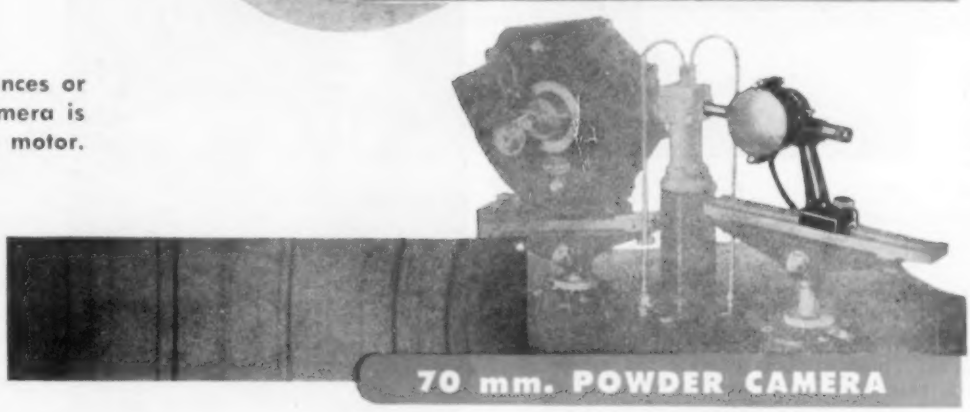
Typical Back Reflection Camera Diffraction Pattern



BACK REFLECTION CAMERA

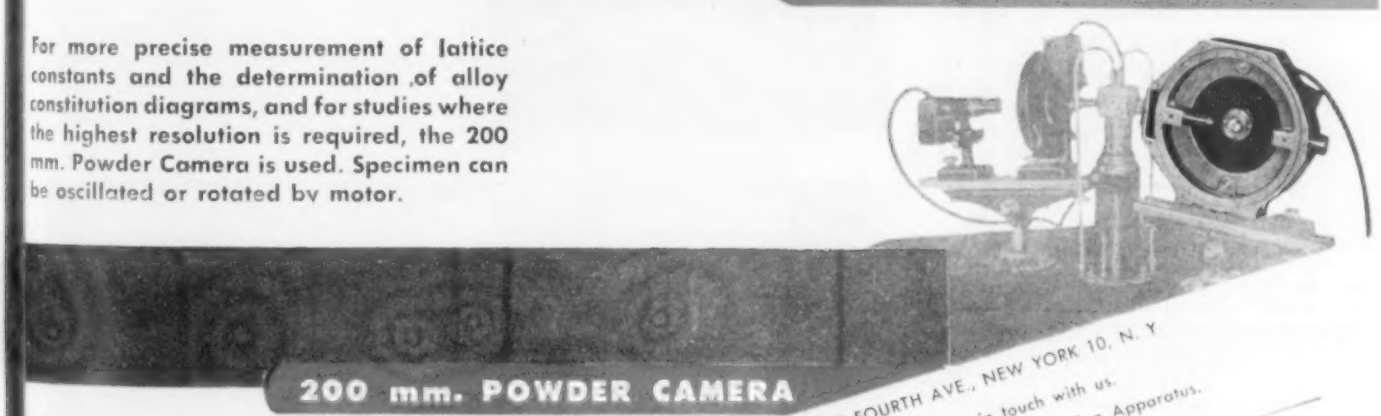
For routine identification of substances or unknowns the 70 mm. Powder Camera is used. Specimen can be rotated by motor.

Typical 70 mm. Powder Camera Diffraction Pattern.



70 mm. POWDER CAMERA

For more precise measurement of lattice constants and the determination of alloy constitution diagrams, and for studies where the highest resolution is required, the 200 mm. Powder Camera is used. Specimen can be oscillated or rotated by motor.



200 mm. POWDER CAMERA

Typical 200 mm. Powder Camera Diffraction Pattern. Note the greater resolution of lines as compared with the 70 mm. pattern of the same area above.

YOUR LOCAL PICKER ENGINEER IS AS NEAR AS YOUR PHONE — OR USE THIS COUPON

PICKER X-RAY CORP., 300 FOURTH AVE., NEW YORK 10, N. Y.

☐ Please have your local engineer get in touch with us.

☐ Please send literature describing Picker Diffraction Apparatus.

NAME _____

TITLE _____

COMPANY _____

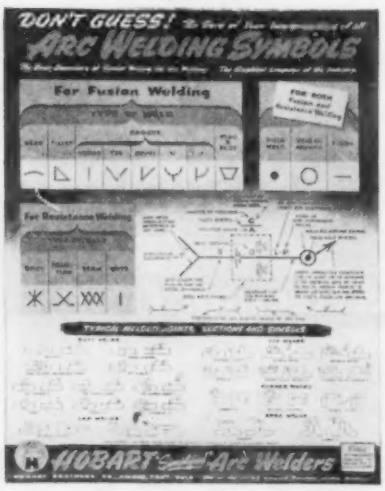
CITY _____ STATE _____

(attach to your company letterhead)

WELDING CHART

An entirely new and informative wall chart, illustrating the basic characters of welding symbols recommended as American Standard by the AMERICAN WELDING SOCIETY, has been published by The Hobart Brothers Co., Troy, Ohio.

The graphical language of the welding industry is illustrated separately for Fusion Welding, for Resistance Welding, and for those requiring both Fusion and Resistance Welding. The location of the Symbols, numerical and other data on the reference line always has definite significance and this is illustrated to show the standard manner of placing proper information on the Symbols.



Twenty-three typical welded joints and sections, covering butt welds, lap welds, tee welds, corner welds and edge welds, are well illustrated and marked with the standard welding symbols applying to that particular joint or section.

These symbols provide the means of placing complete welding information on the drawings and the Hobart Welding Symbol Chart, printed in three colors on heavy paper suitable for hanging on the wall of the drafting room and welding booth will be sent without charge to designers, inspectors, welding operators and others concerned with the safety and efficiency of welding fabrication.

FROSTRODE PRODUCTS MOVES INTO LARGER PLANT

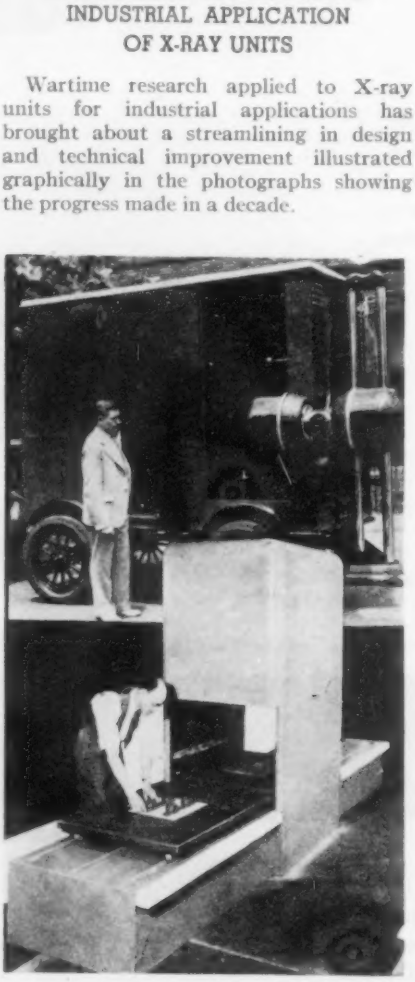
In order to meet increased demands for industrial refrigeration equipment by industry, Frostrode Products has moved to a larger plant at 19929 Exeter, Detroit 3, Mich. The new plant facilities will permit stepped-up delivery schedules on Frostrode refrigerated welding units, the company's line of Frostpoint resistance-welding electrodes, Frostrode coolant coolers, low-temperature cabinets and cold-treating equipment, as well as earlier production on new and improved products under development at the present time.

CALIFORNIA STATE DEPARTMENT OF EDUCATION

Unit Course in Oxygen Cutting with Emphasis on Marine Burning. 1944. 187 pp., illus. State Director of Vocational Training for War Production Workers, State Department of Education, Library and Courts Building, Sacramento 14, Calif. Single copies $1.25; 10 or more copies $1.10 each.

STREAMLINED REFINEMENTS IN INDUSTRIAL APPLICATION OF X-RAY UNITS

Wartime research applied to X-ray units for industrial applications has brought about a streamlining in design and technical improvement illustrated graphically in the photographs showing the progress made in a decade.



At the top is an "antique" version of an industrial X-ray unit built by the Kelley-Koett Manufacturing Co., Covington, Ky. in 1934. Cabin and table are shown mounted on a Ford motor truck.

Today's production pattern is illustrated in the bottom photograph showing the modern Kelley-Koett radiographic cabinet. The 1944 unit shown in contrast to the early effort is only one of a wide variety of designs based on functional demands.

Kelley-Koett engineers are probing the possibilities of many new applications of X-ray and fluoroscopy to postwar industrial uses and the consequent attributes of making industrial testing more certain and speedier than prevailed in prewar days.

MACHINERY AND WELDER CORPORATION BUILDING

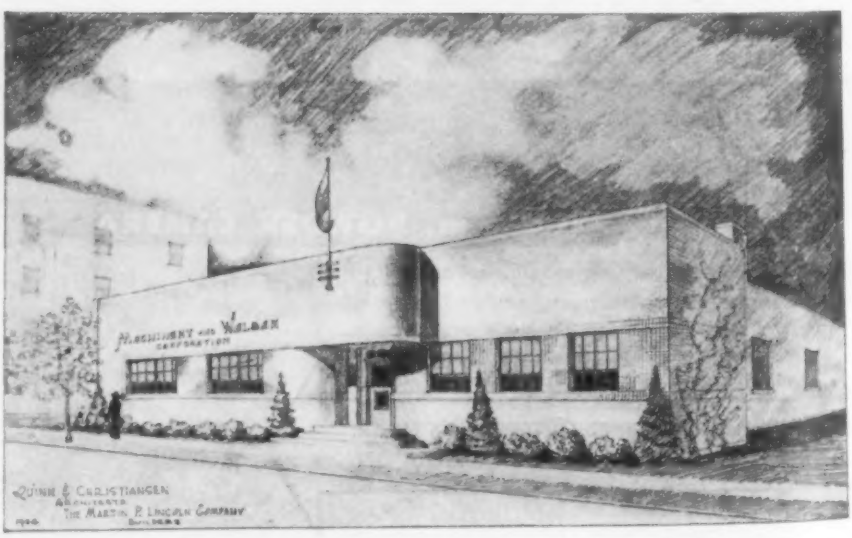
The Machinery and Welder Corp. will move to its new building at 1324-26 West Fulton St., Chicago, Ill., some time this month.

The new quarters represent a twofold increase in space and permit heavier operations. (See sketch below.)

The Machinery and Welder Corp. started in 1931 from a single office in Chicago and built its business to the point where it has offices in Moline, Milwaukee and St. Louis. The territory services cover northern Indiana, all of Illinois, Wisconsin, Iowa and Missouri.

The building is to be a one-story brick building with concrete floors to handle the heavy storage floor loads. Of special interest is the roof construction which is especially designed and manufactured by the Airtherm Manufacturing Co. in St. Louis, Mo. Its roof is unique in its ease of application, ease of construction and is all welded.

Machinery and Welder are exclusive distributors for the General Electric line of arc-welding equipment, electrodes and accessories and the Arcos line of stainless steel and a complete line of arc-welding equipment, electrodes, and accessories as well as gas welding and cutting accessories and electrodes, and its service covers the resistance welding field.



How Much Can *You* Cut the Cost

OF DEPOSITING WELD METAL?

The table at right shows typical cost reductions made possible by carefully selecting the largest size electrode practical for the job at hand. This accurate study takes into account all factors such as labor, overhead, power, electrode costs, etc. Note the progressive lowering of cost as electrode size is increased.

That's one reason why WSR (Welding Service Range) is so important. It tells you exactly the usable welding current your machine will deliver, from minimum to maximum. You know what size electrodes you can properly handle.

The ample capacity of P&H Welding machines is due to their more liberal use of copper—more efficient operation. Start *now* to speed all kinds of welding work—and cut your welding costs. Ask about the WSR rating for the P&H Arc Welder most suitable for your class of work.

Cost per pound of depositing weld metal with AWS, E-6010 Electrode.

Electrode Size	Cost per Pound
1/8"	$2.56
5/32"	2.05
3/16"	1.72
1/4"	.99
5/16"	.74
3/8"	.55

P&H WSR Models are built in a range of capacities to handle all sizes of electrodes from 1/8" to 3/8"—all with a single heat control. "Visi-matic" Calibration enables the operator to select the exact current required for each of the three basic groups of electrodes.

P & H ARC WELDERS

WSR (Welding Service Range) ratings are given for all P&H Arc Welders. Ratings are based upon the actual output of each machine, enabling you to buy more wisely on the basis of cost per ampere.

60 YEARS OF SERVICE — FOUNDED IN 1884 — QUALITY P&H SERVICE — 1884 1944

Ask also about P&H Welding Electrodes, available in all sizes and types for production and maintenance welding. Send for literature.

General Offices:
4551 West National Avenue Milwaukee 14, Wisconsin

HARNISCHFEGER CORPORATION
ARC WELDERS • EXCAVATORS • ELECTRIC CRANES P&H MOTORS • HOISTS • WELDING ELECTRODES

Canadian Distribution: The Canadian Fairbanks-Morse Co., Ltd.

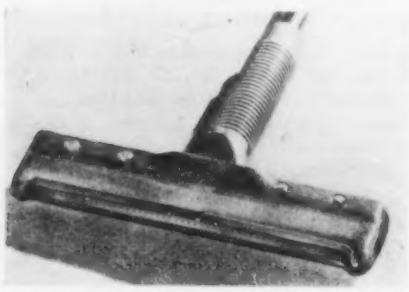
NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

FLAME PRIMING AND DESCALING NOZZLES

Currently there is much interest in flame priming and descaling, the modern method to remove rust scales from steel plate and prepare it for painting.

The new Victor Standard Descaling Attachment is easily attachable onto any standard Victor welding torch butt. It can also be furnished with torch butt to those who are not owners of Victor equipment.



This particular flame-priming and descaling nozzle has many advantages:

1. It is provided with an unusually well-designed *Spiral Mixer and Gas Proportioner* to handle with greater efficiency the larger gas volumes required for these operations.
2. This mixing device virtually assures freedom from backfire or flash-back.
3. In order to keep premixed gases below ignition temperatures, even within the proximity of the ribbon flame and deflected heat, an *Airadiator* aluminum cooling section is incorporated at the nozzle head.
4. Replaceable Meehanite skid shoes with properly shaped lugs add substantially to wearing life of the nozzle and allow it to be dragged at any suitable angle over the metal surfaces to be cleaned.

This nozzle is made in 4-in. (Model 361) and 6-in. (Model 362) ribbon flame widths. For inaccessible areas or rivet heads, special Circular Multi-Flame Nozzles are available.

UNIVERSAL RESISTANCE WELDER

One of the most important new developments in resistance welding in many years will be announced at the Metal Show in Cleveland, October 16th to 20th, by Progressive Welder Co., 3050 E. Outer Drive, Detroit 12. The machine is a Universal resistance welder—capable of either spot welding or seam welding—and operated by storage batteries rather than through transformers from power lines, etc.

While a complete line of battery-operated welders is being put on the market by Progressive Welder Co., the model to be shown at Cleveland will permit performing of welding operations heretofore considered impractical. These include the spot welding of structural aluminum sections of considerable thickness (up to $^3/_{16}$ in. or more) and the seam welding of aluminum of the same thickness at high speeds. In addition to the radically new welding equipment, one of the contributing factors in making the latter operation possible is an entirely new development in seam welder wheel design originated by Frostrode Products, 19929 Exeter, Detroit 3. This wheel, it is understood, is internally refrigerated, requiring no external water supply, and has a replaceable rim, reducing wheel renewal cost when the wheel is worn. It is thus similar to the replaceable caps on Frostpoint spot-welding electrodes previously available.

WELDALENE, A NEW FLUX

Manufacturers of coated welding rod are invited to investigate the possibilities of a new addition to Foote Mineral Co.'s comprehensive list of welding fluxes—known as Weldalene.

Weldalene is not "just another" flux. It is believed to fill a long-standing gap in fluxing materials. Among its properties, suggesting use in mild steel and stainless rods (A. C. or D. C.) are:

1. Unusual sintering characteristics. Weldalene sinters 220° F. before it is vitreous as compared to a range of 120° F. for a typical Potash Feldspar. Weldalene deforms 100° F. before it is vitreous compared to 20° F. for a typical Potash Spar. Consequently, Weldalene is an active flux over a wide range of temperature, which suggests a means of controlling slag fluidity.
2. Weldalene is "silica hungry." Its ratio of alumina to silica is 24 to 60%, indicating that Weldalene—by reacting with free silica—may reduce silica included in weld metal.
3. Weldalene contains a substantial percentage of potassium, assuring greater arc stabilization.

From recent studies and commercial applications, it can be reported that Weldalene is an excellent vitrifying agent contributing to the glassy phase which combines other ingredients together more strongly. This property suggests that Weldalene might be used advantageously to increase the dry strength of coatings, eliminating to a degree unnecessary wastage or partially consumed electrodes. Foote Mineral Co., 1611 Summer St., Philadelphia, Pa.

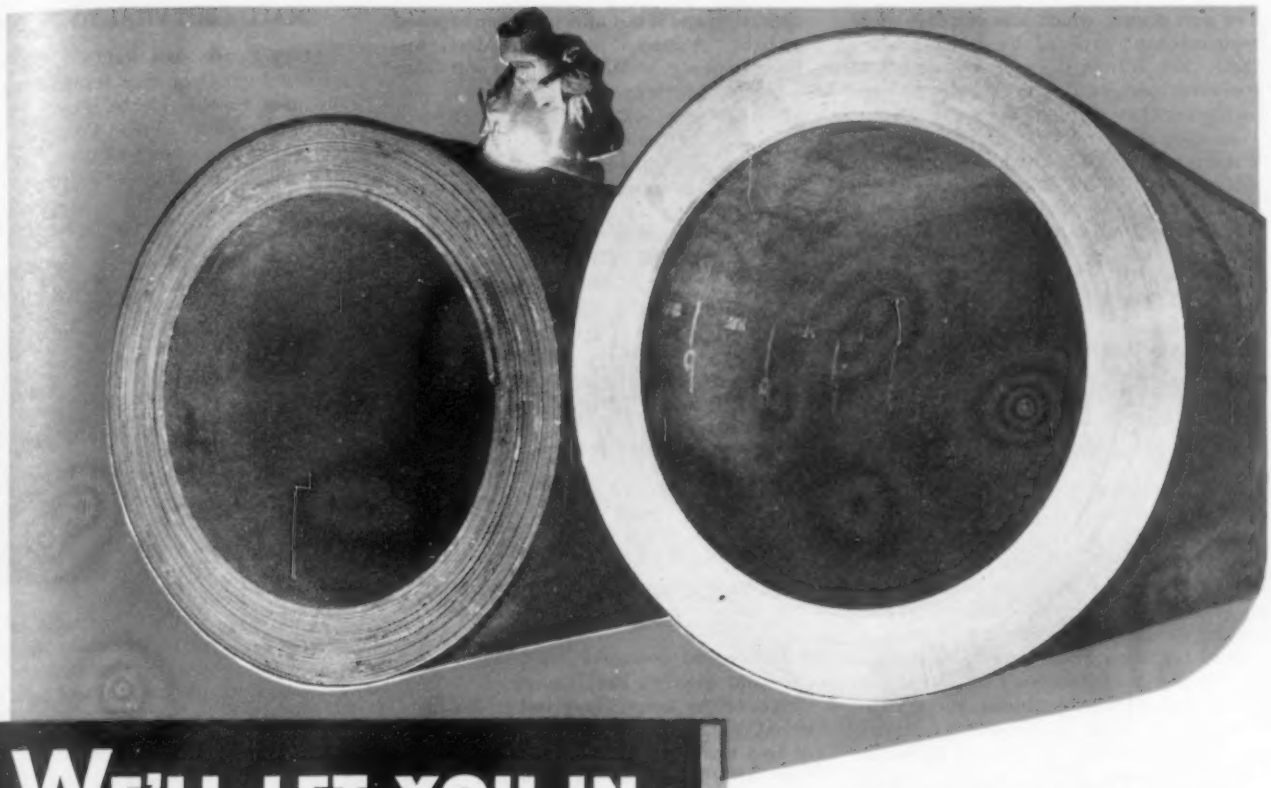
NEW METHOD OF HARD-FACING SUGAR-CANE MILL KNIVES

A new method of hard-facing sugar cane mill knives, to lengthen their efficient cutting life, has been developed by Haynes Stellite Co., a Unit of Union Carbide and Carbon Corp. Knives hard-faced by the new procedure are designed to stay sharp longer, and will thus save shutdowns for resharpening. This means, also, a higher recovery of cane sirup, since less sirup is lost when the cane is cut clean than when it is crushed by a dull knife.

The knife, protected by what amounts to an inserted core of hard, wear-resistant metal, is inexpensive. It can be made of steel boiler plate by any reliable welding or machine shop. Yet when completed, it is self-sharpening, sharpening itself evenly as both sides wear.

To make knives by this procedure, a blank blade is cut from steel plate, and the outer circular edge is rabbeted to provide a recess with a depth slightly more than half the knife thickness. Rabbeting is done on a milling machine. Then Haynes Stellite cobalt-chromium-tungsten hard facing alloy is applied to the recessed area. This layer is covered with a thin layer of steel by oxyacetylene welding and the steel is then built up by the metallic arc process to fill the remainder of the recess. After the edge is sharpened by grinding 15° bevels on both sides, the knife surface is ground flat and is ready for use.

Previous efforts to prolong the life of these knives consisted of hard-facing either both sides or only one side of the double-beveled cutting edge, or beveling only one side and hard-facing the other side. In the latter two designs, the knives tended to be self-sharpening but the cutting edge was not centered, resulting in unbalancing of the mill and unsatisfactory cutting.



SMITHway Electrodes in action *on sections for a SMITHway Multi-Layer Vessel (on the right after machining); 42 inches in outside diameter with 5½-inch wall thickness; for operation in a war plant at 4,500 pounds per square inch.*

WE'LL LET YOU IN ON THE SECRET OF THIS WEAPON

WHEN the war started, everybody—including the Axis—was sure American industry couldn't build enough high-pressure vessels to produce the immense quantities of explosives necessary for waging global war. There just wasn't enough forging capacity available to turn out these giants, but Multi-Layer welded construction, pioneered by the A. O. Smith Corporation, solved the problem.

What does this mean to you? Just this: if you do big, tough welding jobs, we can supply you with the same kind of SMITHway Certified Welding Electrodes that we use in the production of some of the world's largest, most exacting welding jobs.

SMITHway Certified Welding Electrodes are the best that money can buy because we have a double interest in making them right. No other electrodes go through as thorough production controls—are so scientifically checked and rechecked both in the laboratory and on the production floor.

The code number on every box of SMITHway Certified Welding Electrodes is your assurance that they will give you better welding results at lower costs on the big jobs that you and we call upon them to do. Specify SMITHway Certified Welding Electrodes. Made *by* welders—*for* welders.

Mild Steel . . . High Tensile . . . and Stainless Steel

WELDING ELECTRODES

made by welders . . . for welders

Have You Bought That Extra War Bond This Month?

SMITHway Welding Monitor cuts the time of training welders as much as 33⅓%.

SMITHway AC Welding Machines reduce spatter, completely eliminate "arc blow."

A. O. SMITH Corporation

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Offices at: NEW YORK, PITTSBURGH, CHICAGO, TULSA, HOUSTON, LOS ANGELES, SEATTLE

In Canada—JOHN INGLIS CO., LIMITED

The new design, which also employs more wear-resistant type of hard-facing alloy than that formerly used, corrects this condition, maintaining at all times an edge no thicker than the alloy deposit.

In addition to maintaining balance and a sharp edge, hard-facing alloy applied by this method can be extended to a greater depth within the blade at the points of greater wear, thereby compensating for nonuniform wear of the blade along its length.

Details on how to apply this hard-facing procedure are available upon request from Haynes Stellite Co., Kokomo, Ind.

IMPROVED SOLDERING STAND

The new model SS10 Soldering Stand, developed by the Ess Specialty Corp. of Bergenfield, N. J., embodies changes in the design and construction for greater protection against injurious fumes, hand fatigue, eye strain, etc.—increasing soldering production and efficiency.

SS10 Soldering Stands are being widely used by many of America's most modern production lines. In almost every case where they are now in use additional units are being employed as rapidly as facilities are increased.

The Stands permit maximum freedom for work passing, enable the operator to focus attention on the soldered joint by means of the magnifying or plate glass window thus quickening the pace of soldering by elimination of all lost motion.

For further information address Department SS, Ess Specialty Corp., Bergenfield, N. J.

NEW ANTIFOG COMPOUND

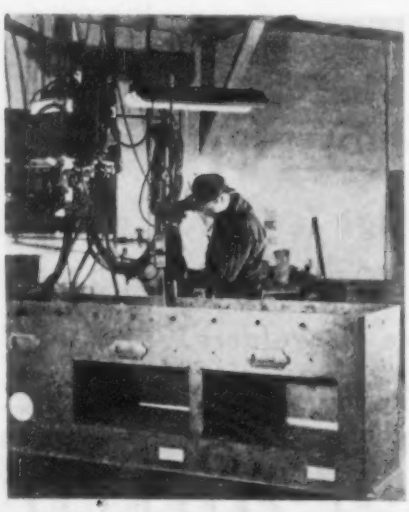
Merix—a new antifog liquid compound that prevents the forming of mist, fog or steam on any type of glass or plastic surface. Now available in large quantities, this antifog preventive has been a boon to industries where large amounts of plastic and glass surfaces are in constant use. It is easily applied, lasts a long time, is noninflammable, nontoxic, nonacid, keeps indefinitely and is not affected when exposed to light. A modest amount of Merix, applied to any glass surface with a soft cloth or cotton batting, forms an invisible protective film which keeps surface free of mist, fog or steam for indefinite periods. Ideal for windshields, goggles, eyeshields, camera lenses, optical airplane instruments and any other glass or plastic surface where temperature variations between inside and outside, moisture, fog or steam cause these areas or instruments to become foggy. In addition, Merix cleans glass and plastic surfaces without harming the softest plastic so as to remove any form of dust, dirt or fingerprints and to assure clearest possible vision.

Merix is manufactured by the Merix Photo Co., Dept. 95, Wrigley Building, Chicago 11, Ill.

PORTABLE WELDING GUN BREAKS BOTTLE NECK

Helping to overcome manpower shortages and speeding the delivery of cooking ranges to the Army, Navy and U. S. Maritime Commission is the production record of this heavy-duty portable spot-welding gun installation at Washington Stove Works, Everett, Wash. The installation was developed and produced by Progressive Welder Co., 3050 E. Outer Drive, Detroit 12, Mich.

These assemblies were formerly riveted, the process requiring 1½ hr. or longer. As the body of a large range is too heavy to be spot welded on conventional stationary equipment, a spot-welding gun—suspended by cables from above and counterbalanced so that it can be moved in any direction—is used. This permits the electrodes to be brought to bear readily on any desired point of the range body, cutting production time for this assembly operation to 15 min. or less. Possibilities of either burning the metal or underwelding are eliminated by automatic time and heat controls.



Washington Stove Works plans to use this same type of portable welding installation to produce and improve the quality of its commercial ranges for post war.

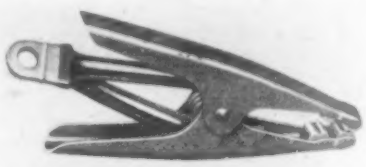
SMALL! BUT VITAL TO VICTORY

Mary Curtis spot welds small parts of an ultrahigh frequency transmitting tube together at the Dobbs Ferry plant of North American Philips Co., Inc. Grids for such tubes consist of many fine wires which must be aligned perfectly—otherwise communications equipment for our fighting men will not function properly.

The company is also producing cathode ray tubes, quartz crystals, fine wire electronic measuring instruments and X-ray equipment (medical and industrial) for war purposes.

LOW-COST GROUND CLAMP

A new ground clamp for welders priced at only $1.50 has just been announced by The Lincoln Electric Co., Cleveland, Ohio.



New Lincoln Ground Clamp for Welding Units Features Low Price and Dual-Jaw Connection for Carrying Current

Besides its low cost, the clamp is designed so that each jaw connects independently to the ground cable. Thus, if one jaw is prevented from making a good electrical contact, due to any reason such as heavy scale, paint, etc., the other jaw will carry the current.

The ground clamp has a heavy-duty processed steel frame with durable copper conductors and contacts. The unit weighs only 1½ lb., has a maximum jaw spread of 2½ in. and a rating of 300 amp.

Annual Meeting

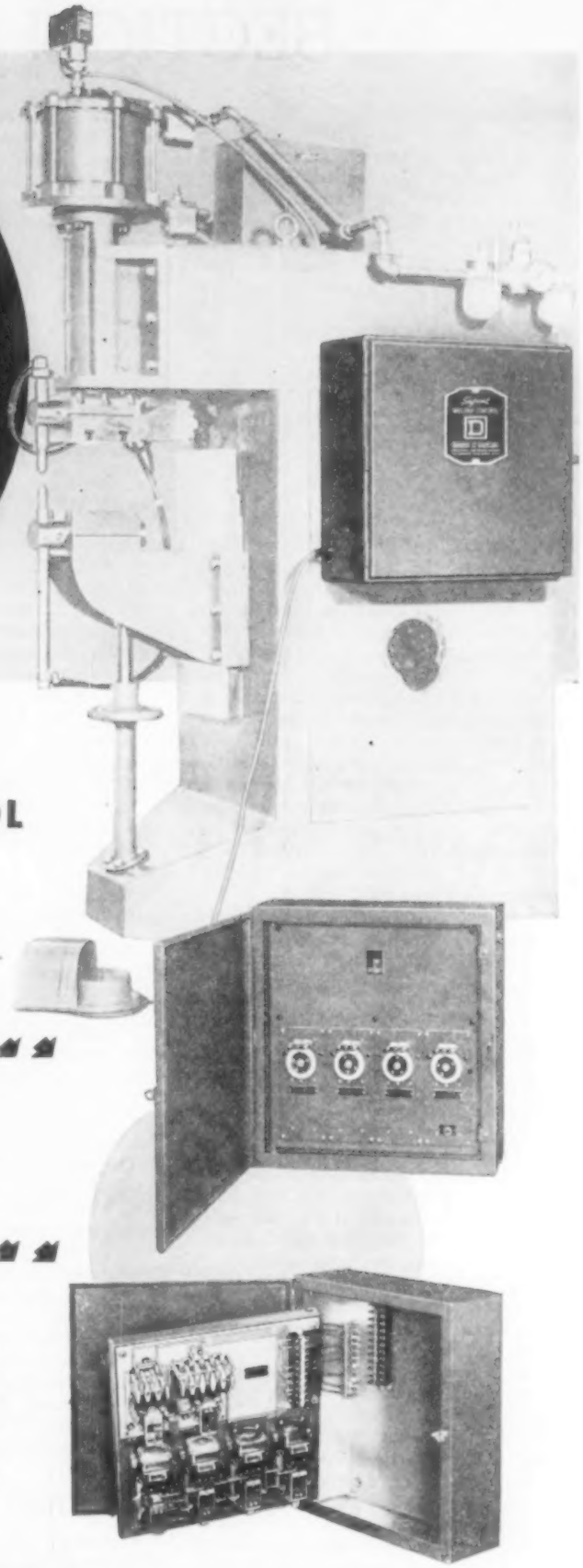
American Welding Society

Hotel Cleveland

Oct. 16–19

Cleveland, Ohio

SIMPLICITY *and* ACCESSIBILITY



Outstanding Features of *Safront* WELDER CONTROL

SIMPLICITY! Only simple magnetic relays and pneumatic timing units are used in the assembly of Safront Weld and Sequence Timers. Circuits are conventional—easy for the electrician to understand and service. Individual pneumatic timing relays govern each step in the resistance welding cycle. Operation is based on the interval required to transfer a small volume of filtered air from one chamber to another, through a regulated orifice.

ACCESSIBILITY! Loosening two screws permits swing-out of the Safront timer panel. Control relays, timing relays, terminals and wiring are instantly accessible for inspection or maintenance. Coils, contacts and all renewable parts may be replaced, in a matter of seconds, using only a screwdriver and pliers.

★ ★ ★

Standard types of Safront timers are available to meet practically all resistance welding requirements. Safront construction places all electrically "live" parts behind a protective panel, yet provides large calibrated dials with knurled adjusting wheels in front, for finger-tip adjustment of individual timing periods.

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SECTION ACTIVITIES

BIRMINGHAM

The following officers and executive committee have been elected for the year 1944–45 by the Birmingham Section.

Chairman, W. B. Browning, The Linde Air Products Co.; *Vice-Chairman*, J. E. Durstine, The Lincoln Electric Co.; *Secretary-Treasurer*, W. L. Poole, Air Reduction Sales Co.

Executive Committee: (term expiring May 1945) R. E. Jones, E. W. Braun, E. H. Anchors and J. W. Adams; (term expiring May 1946) F. E. McAtee, J. Thompson Vann, B. B. Kullen and C. C. Pinckney.

CHATTANOOGA

Mr. George F. Wolfe of the Dravo Corporation was the guest speaker at the October meeting of the Chattanooga Section. Mr. Wolfe spoke on "Production Line Assembly Methods Applied to Ship Construction."

Dr. W. G. Theisinger of Lukens Steel Co. will speak on "The Manufacture and Fabrication of Clad Steels" at the November meeting.

Mr. L. G. Pickhaver of General Electric Co. will be the speaker at the December meeting, on "Atomic Hydrogen Arc Welding."

Mr. John B. Tinnon of Metal and Thermit Corp. will speak on Thermit Welding at the January meeting.

Mr. T. B. Jefferson, editor of *The Welding Engineer*, will speak on "Welding in the Post-War World" at the March meeting.

DETROIT

Considerations in successful welding of heat-treated alloy steels were outlined by C. E. Altenburger, research engineer of Great Lakes Steel Corp. at the first meeting of the season of the Detroit Section, held Sept. 8th, at Rackham Memorial Bldg. A similar meeting of the Flint division was held the preceding night. More than 250 turned out for the two affairs.

When parent metal is harder than the weld deposit, as in armor plate and other heat-treated alloy welded with austenitic rod, the speaker stressed the necessity of making the joint gap a broad one, to provide enough metal for elongation under shock.

The method of forming the crown is equally important, he pointed out. He recommended laying of stringer beads at the crown edges before filling in. These beads materially reduce the notch strength of the adjoining parent metal, due to their sudden heating and cooling effect. But if they are followed by beads laid between them, the heating of the adjoining parent areas in effect draws them, improving performance by relieving the brittleness. If the final bead is on an edge rather than the center, the near-by area is likely to fail under shock load.

As other criteria of successful butt welding, Mr. Altenburger recommended as flat a crown as possible, saying that convexity weakened strength; and he also called for care to prevent inclusion of parent metal with the weld metal by washing in, thereby dissipating the strength of the weld metal.

In discussion of ferritic welds, the speaker described research establishing that aging improved ductility, although it did not affect tensile strength and yield. Even a few hours on a steam radiator is time enough to create considerable difference in elongation and area reduction, he stated.

Musical entertainment provided by Murray Corp. preceded the program.

MARYLAND

The following is the program of meetings of the Maryland Section for the season.

Nov. 17, 1944—"Welding Steels of High Hardenability," Mr. G. E. Linnert, Welding Engineer, Rustless Iron and Steel Corp.

Jan. 19, 1945—"Welding in Shipbuilding, Mr. LaMotte Grover, Welding Engineer, Air Reduction Sales Co.

Feb. 16, 1945—Not yet completed.

Mar. 16, 1945–"The Future of the Welding Operator," Mr. A. C. Earlbeck, The Lincoln Electric Co.

May 18, 1945—Symposium.

Dinner will precede the meetings, both to be held in the Engineers' Club, 6 West Fayette Street, Baltimore.

NEW YORK

The New York Section held the first of its regular technical meetings for the 1944–45 season on Tuesday, September 12th, at the Engineering Societies Building. Technical Chairman for the evening was E. B. Stolle, Midwest Piping & Supply Co., Inc., New York.

The feature of the evening's program was the showing of the new sound color film, "The Story of A.-C. Welding" produced by the General Electric Co. R. F. Wyer, Application Engineer, General Electric Co., introduced the film and conducted the discussion period following its presentation.

The evening started with the regular half-hour question and answer period conducted by E. Vom Steeg, Jr., Welding Engineer, General Electric Co., New York. Refreshments were served following the formal part of the program.

PASCAGOULA

The newly organized Pascagoula Section has appointed the following officers and chairmen of committees.

Chairman, W. B. Bowen; *Vice-Chairman*, Charles Dick; *Secretary-Treasurer*, Milton Forman, Ingalls Shipbuilding Corp. *Members-at-large*, Thomas Dawson, Sidney Swan, A. M. Swigert. *Chairman, Program Committee*, R. H. Macy; *Chairman, Problems Committee*, Les J. Blackford; *Chairman, Membership Committee*, John Glennon.

PITTSBURGH

Meetings of the Pittsburgh Section scheduled for this season are as follows:

Oct. 25, 1944—"The Story of Resistance Welding," G. N. Sieger, President, S-M-S Corp.

Nov. 15, 1944—"Salvage Operations at Pearl Harbor and After Dec. 7, 1941," Frank E. Thompson, The Thompson Engineering Co.

Jan. 17, 1945—"Application of Magnetic Particle Testing to Weld Inspection," C. E. Betz, Vice-Pres., Magnaflux Corp.

Feb. 21, 1945—"Welding of Copper and Copper Alloys," John J. Vreeland, Sales Promotion Division, Chase Brass & Copper Co.

March 21, 1945—"Steel Castings—Their Use in Weldments," E. J. Wellauer, Supervisor, Research and Metallurgy, The Falk Corp.

April 27, 1945—Eighth Annual Tri-state Convention—"Welding in the Post-War World," T. B. Jefferson, Editor *The Welding Engineer*.

Question and Answer Period to precede each meeting. Conducted by L. C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corp.

All meetings will be held in the Auditorium of the Mellon Institute of Industrial Research Building, 4400 Fifth Ave. (Oakland), Pittsburgh, Pa.

PORTLAND, MAINE

At an organization meeting held August 31st, the following officers were elected for this newly organized Section:

Chairman, A. R. Schwerdtfeger; *Vice-Chairman*, Henry Henderson; *Secretary-Treasurer*, Leonard W. Cooper; *Trustee*, William M. Briggs. *Directors:* (2 years) B. O'Donnell, K. H. Boyington, J. LeFebvre; (1 year) E. M. Thompson, R. Staires, I. Anzmann.

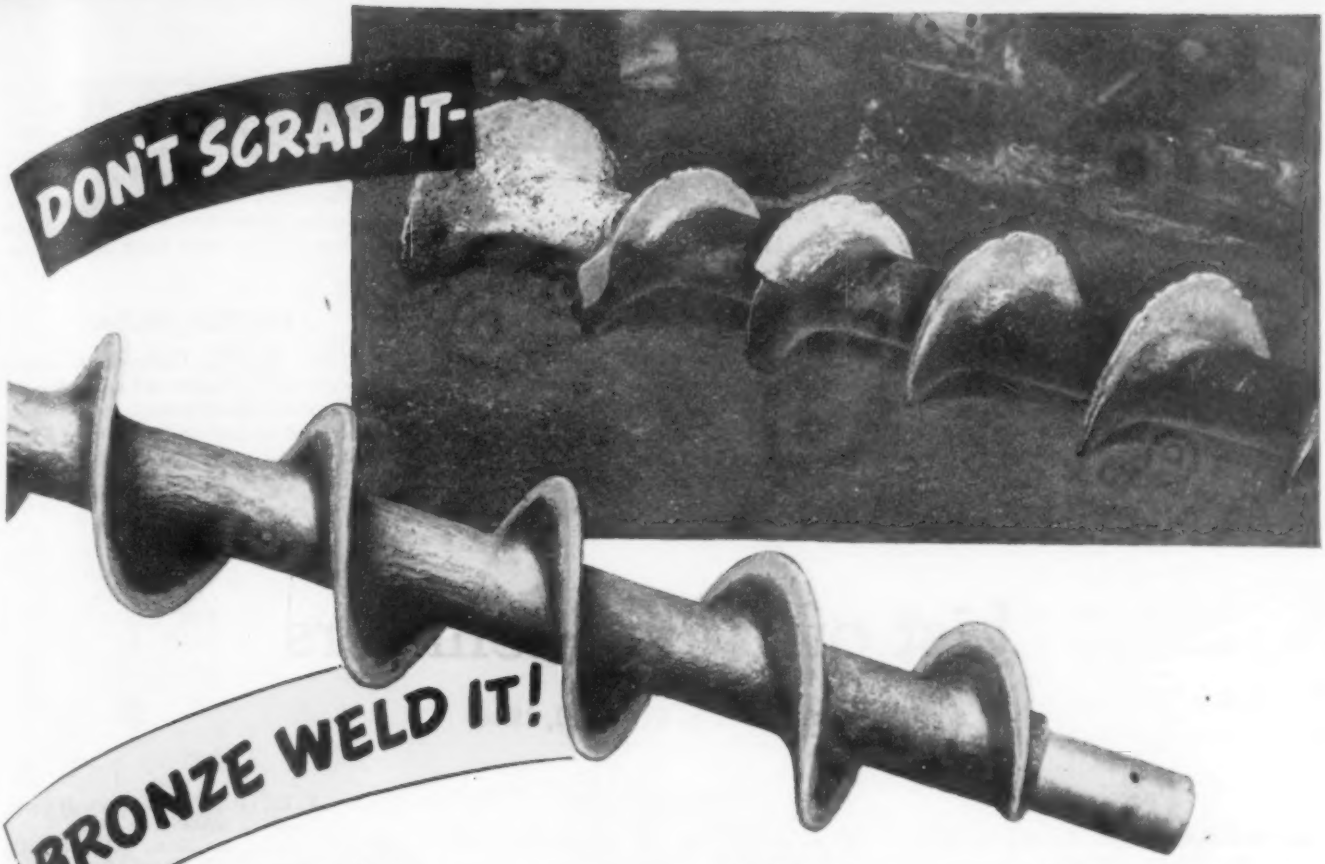
ST. LOUIS

Newly elected officers of the St. Louis Section are as follows:

Chairman, W. S. Evans, Curtiss-Wright Corp.; *Vice-Chairman*, C. H. Armstrong, Curtis Mfg. Co.; *Treasurer*, G. O. Bland, Hill Equipment & Eng. Co.; *Secretary*, H. C. Close, Machinery and Welder Corp.; *Directors:* N. F. Moss, C. L. Hibbler, E. F. Meier, G. Derickson, A. Allina, I. T. Olson. *Chairman, Membership Committee*, N. F. Moss, Wagner Electric Corp. *Chairman, Program Committee*, I. T. Olson, The Linde Air Products Co.

WESTERN NEW YORK

A new meeting place is under discussion by the Section and full details will be announced shortly.



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The Second Annual Golf match was held on August 16th, but due to the gas shortage, the extreme urgency of business and particularly the rain, the attendance was not all that could be hoped for.

YOUNGSTOWN

The newly elected officers for 1944-45 are as follows:

Chairman, Arthur W. Waldo, Youngstown Welding & Eng. Co.; *Vice-Chairman*, A. B. Alexander, Standard Boiler & Plate Iron Co.; *Secretary-Treasurer*, H. Ross Strobecker, Youngstown Welding & Eng. Co. *Executive Committee*; Lt. D. E. Dallman, T. J. Featheringham, C. J. Heltzel and W. M. Tam.

Employment Service Bulletin

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Hoehler, Alfred E., (B), 26 Earle Rd., Wellesley, Mass.
White, Edmund A., (B), 304 Summer St., Weymouth, Mass.
Wiseman, Elton J., (C), Stone & Webster Engrg. Corp., 49 Federal St., Boston, Mass.
Wolfe, Philip H., (B), 734 Plymouth St., Abington, Mass.

CHICAGO

Boese, William G., (B), 217 W. Ripley St., Michigan City, Ind.
Martin, Howard, (B), 1107 Morris St., Hammond, Ind.

CANTON

Bryan, Henry B., (C), 109 W. Franklin St., Troy, Ohio.
Nalley, Buell M., (C), 904 Kent Lane, Troy, Ohio.

CLEVELAND

Allen, R. W., (C), The Firestone Tire & Rubber Co., Akron 17, Ohio.
Bosomworth, G. P., (B), The Firestone Tire & Rubber Co., Akron 17, Ohio.
Coats, Harry P., (B), Firestone Steel Products Co., Akron, Ohio.
Erb, Carl M., (C), The Firestone Tire & Rubber Co., Akron 17, Ohio.
French, Joel, (B), 3977 W. 224th St., Cleveland 16, Ohio.
Hansen, J. A., (C), Gun Mount Div., Firestone Tire & Rubber Co., 1200 Firestone Pkway., Akron 17, Ohio.
Hardnack, Louis M., (C), 1209 E. 113th St., Cleveland, Ohio.
Harrison, Ralph C., (C), 1261 W. Clifton Blvd., Lakewood, Ohio.
Miller, John L., (B), The Firestone Tire & Rubber Co., Akron 17, Ohio.
Spillar, Frank J., (B), 4277 E. 133rd St., Cleveland, Ohio.

CONNECTICUT

Kroto, Stanley G., (B), Rolock Inc., Fairfield, Conn.
Pennington, H. A., (C), 61 Buena Vista Rd., Bridgeport 4, Conn.
Schneider, Edward A., (C), Chance Vought Aircraft Corp., Materials & Process Dept., Stratford, Conn.

DETROIT

Chase, Reginald, (B), 19920 Waltham Ave., Detroit 5, Mich.
Hopkins, Tal, (B), 7739 W. Eight Mile Rd., Detroit 21, Mich.
Jaffe, Robert, (F), 328 Michigan House, Ann Arbor, Mich.
Johnston, Thomas, (C), 16197 Roselawn, Detroit 21, Mich.
O'Grady, James A., (A), 4001 Beaufait St., Detroit 7, Mich.
Ott, John T., (B), Hudson Motor Car Co., 12601 E. Jefferson Ave., Detroit 14, Mich.
Wetherby, B. R., (A), B. R. Wetherby Co., 403 Donavan Bldg., Detroit 1, Mich.

LEHIGH VALLEY

Grebe, Karl A., (C), Lehigh Structural Steel Co., Foot of Allen St., Allentown, Pa.
Frantz, Chas. F., (C), Lehigh Structural Steel Co., Allentown, Pa.
Newmann, George J., (B), 322 N. 29th St., Allentown, Pa.
Osha, W. C., (B), 1021 E. Front St., Berwick, Pa.
Patterson, W. L., (C), 1939 Cedar St., Allentown, Pa.
Philips, Olin H., (C), American Car & Foundry Co., Berwick 6, Pa.

LOS ANGELES

Brady, James, (B), Waldrip Engrg. Co., 11810 Center St., Hollydale, Calif.
Clark, Basil L., (B), Standard Steel Corp., 5001 S. Boyle St., Los Angeles, Calif.
Felber, Victor L., (C), 1471 Sherbourne Dr., Los Angeles 35, Calif.
Hesley, F. D., (B), Todd Shipyards Corp., P. O. Box 231, San Pedro, Calif.
Mallory, J. L., Jr., Ens., U.S.N.R., (C), Ship Repair Unit, Navy 140, c/o Fleet Post Office, San Francisco, Calif.
Steen, J. W., (B), 27-5 H St., 11-C Camp, Taft, Calif.

LOUISVILLE

Dettmar, William, (B), American Air Filter Co., 215 Central Ave., Louisville 8, Ky.
Miller, Lloyd M., (C), 312 Mill St., Madison, Ind.

MILWAUKEE

Allen, D. B., (B), Box 196, Baraboo, Wisc.
Baldt, Otto, (C), 2344 N. 65th St., Milwaukee, Wisc.
Petushek, Anthony, (C), 2224 W. Mitchell St., Milwaukee, Wisc.

NEW JERSEY

Bruno, Stephen, (C), 714 Fairview Rd., Woodlyn, Delaware Co., Pa.
Crawford, C. A., (C), 3-15 Hartley Pl., Warren Pt., N. J.
Davis, Norman, (C), Thermacote Co., 120 Arlington St., Newark, N. J.
Ellis, Steven J., (B), Box 83, Passaic, N. J.
Hourahan, Cornelius D., (B), P. O. Box 237, Keyport, N. J.
Hussey, Albert R., (B), 127 Page Ave., Lyndhurst, N. J.
Loehnert, Arthur, (C), 335 Tontine Ave., Lyndhurst, N. J.

NEW YORK

Bandini, Robert H., (C), 47-21 157th St., Flushing, L. I., N. Y.
Barkley, Wm. O., (B), Lehigh Structural Steel Co., 17 Battery Pl., New York, N. Y.
Forgan, Robert C., (B), Air Reduction Sales Co., Arcwelding Sales Dept., 60 E. 42nd St., New York, N. Y.
Knapp, Allen, (C), c/o Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.
Kulbitsky, William, (C), 434 E. 5th St., Brooklyn, N. Y.

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Hays, F. J., (C), 1405 Westwood Ave., Oklahoma City, Okla.
Hotchkiss, Ed., (C), 1225 S. W. 35th, Oklahoma City, Okla.
House, Denver R., (C), 1717 N. W. 3rd St., Oklahoma City, Okla.
Kuchynka, Albert, (C), 1212 S. W. 26th St., Oklahoma City, Okla.
Moeller, Wesley H., (C), 127 S. W. 26th St., Oklahoma City, Okla.
Schlire, John C, (C), 1117 S. W. 27th, Oklahoma City, Okla.

PASCAGOULA

Bruce, J. L., (C), 1104—12th St., Pascagoula, Miss.
Faulkenberry, C. H., (C), 912 Williams St., Pascagoula, Miss.
Hartfield, James C., (C), 921 Buena Vista St., Pascagoula, Miss.
Hopkins, Frank R., (C), 1404 E. Tyler Ave., Pascagoula, Miss.
Hosey, Fred H., (C), Box 248, Kreole, Miss.
Judy, E. M., (C), 608—13th St., Pascagoula, Miss.
Knight, J. C., (C), 1204 E. Lincoln Ave., Pascagoula, Miss.
Martin, J. H., (C), Box 607, Pascagoula, Miss.
McCann, John H., (C), 505—11th St., Pascagoula, Miss.
Mize, J. L., (C), 918 Washington Ave., Pascagoula, Miss.
Smith, David C., (C), 917 Cherubusco St., Pascagoula, Miss.
Tipton, Edward J., (C), Rt. 2, Pascagoula, Miss.

PEARL HARBOR

Moffatt, Charles L., (C), 720-B Kamoku St., Honolulu 36, T. H.
Russell, James E., (B), Apt. S-2 808—16th St., C. H. A. 3, Honolulu, T. H.
Weston, John A., (C), 836—17th Ave., Honolulu 14, T. H.

PEORIA

Bartel, Leonard R., (C), 1403 Ellis, Peoria 5, Ill.
Cornet, Marion G., (C), 4400 Knoxville St., Peoria, Ill.
Rench, Ray M., (C), Edelstein, Ill.

PHILADELPHIA

Chalmers, Russell F. (B), P. O. Box 101, Oreland, Pa.
Fry, Alfred G., (C), 6521 Edmund St., Philadelphia, Pa.
Hopper, Clarence H., (C), J. G. Brill Co., 62nd & Woodland Ave., Philadelphia 42, Pa.
Isbrandt, R. H., (C), G & A Aircraft, Inc., Pitcairn Field, Willow Grove, Pa.
Lutzo, John, (C), 2253 S. Bucknell St., Philadelphia 45, Pa.
Schantz, Orville O., (C), 2118 Washington St., Wilmington, Del.
Stewart, Floyd, (C), 620 W. Front St., Wilmington, Del.

PITTSBURGH

Campbell, Olen, (C), 214 Orchard Lane, Sewickley P. O., Edgeworth, Pa.
Dunn, James A., (B), P. O. Box 183, Ambridge, Pa.
Ehrhardt, Paul T., (C), 116 Thomas Ave., Park Terrace, East McKeesport, Pa.
Franklin, V. A., (C), American Bridge Co., Ambridge, Pa.
Hull, Curtis R., (C), 414 Pine St., Ambridge, Pa.
Povey, Adolph P., (C), 304 Wood St., Pittsburgh 22, Pa.
Sexauer, Guy W., (C), American Bridge Co., Ambridge, Pa.
Sutter, John, Jr., (B), 222—4th St., Beaver, Pa.

PORTLAND, ORE.

Dickinson, Roy L., (B), 6812 N. Smith St., Portland 3, Ore.
Duff, Jack, (B), Frank Duff & Son, Adams, Ore.
Edminster, L. R., (A), Industrial Air Products Corp., 3200 N. W. Yeon Ave., Portland, Ore.
Gilmer, Merritt A., (B), Rt. 1, Box 518, Oswego, Ore.
Gouldsmith, Cecil I., (B), 2277 N. W. Irving, Portland 10, Ore.
Hambro, Stanley P., (B), 915 N. W. 20th 5, Portland 9, Ore.
Lukens, George G., (B), 905 N. W. 20th, Portland 9, Ore.
Pesznecker, S., (C), 8058 S. E. Ogden St., Portland, Ore.
Taylor, Marvin, (B), Apt. 3471, 2102 Broadacrs St., Vanport City, Portland 17, Ore.

PUGET SOUND

Davis, Roncisco H., (C), 146 S. Lafayette, Bremerton, Wash.
Greco, Joseph R., Lieut., (C), A. P. O. 986, c/o Postmaster, Seattle, Wash.
Hammersberg, Glenn, (B), 9218 Mathews Ave., N. E., Seattle 5, Wash.
Harrison, Claude H., (C), Nespelem, Wash.
Ohler, Bud, (C), Bud Welding Supply & Service, 944 Market St., Tacoma 3, Wash.

ROCHESTER

Raudebaugh, R. J., (C), Eng. Dept., Univ. of Rochester, Rochester 3, N. Y.

ST. LOUIS

Andrews, V. E., (B), 933 Tuxedo Blvd., Webster Groves 19, Mo.
Grob, Roy H., (C), 1830 Timberlake, Wellston, Mo.

SAN FRANCISCO

Dodge, Ralph C., (B), Metal & Thermit Corp., E. Grand Ave., South San Francisco, Calif.
Hoffman, Glenn T., (C), U.S.S. *Hall*, DD583, c/o Fleet Post Office, San Francisco, Calif.
Shultz, John M., (C), 1510 San Joaquin St., Richmond, Calif.

SOUTH TEXAS

Earthman, James, (C), Wyatt Metal & Boiler Wks., Houston, Tex.
Morgan, Preston D., (B), Amer. Bureau of Shipping Office, Todd-Houston Shipbldg. Corp., Houston, Tex.

SYRACUSE

Dyer, John B., (B), Easy Washing Machine Corp., Spencer & Solar Sts., Syracuse, N. Y.
Herron, L. B., (B), Easy Washing Machine Corp., Spencer & Solar Sts., Syracuse, N. Y.
Kenan, Laurence M., (B), 2144 S. Geddes St., Syracuse 4, N. Y.
O'Brien, Harold J., (C), Easy Washing Machine Corp., Solar & Spence Sts., Syracuse, N. Y.
Schafer, Harold E., (B), 2208 James St., Syracuse, N. Y.
Seely, Theodore A., (B), Easy Washing Machine Corp., Solar & Spence Sts., Syracuse, N. Y.

WESTERN MASSACHUSETTS

Bell, William M., (B), 244 Oak St., Indian Orchard, Mass.
Brennan, John J., (B), Somers, Conn.
Burnett, Allan, (B), 4 North St., South Hadley Falls, Mass.
Cochran, Ernest, (B), 131 North St., Suffield, Conn.
Duggan, John J., (C), 140 Oak St., Indian Orchard, Mass.
Flynn, Robert J., (C), 37 Frankwyn Terrace, East Longmeadow, Mass.
Fox, George E., (B), 164 Maple St., Springfield, Mass.
Geoffrion, George T., (B), c/o Hampden Cornice Wks. Inc., 218-226 St. James Blvd., Springfield, Mass.
Jones, John E., (B), 41 Embury St., Springfield, Mass.
Jones, Thomas P., (B), 22 Geneva St., Indian Orchard, Mass.
Labossiere, Albert, (B), 396 Worcester St., Indian Orchard, Mass.
Labossiere, Leo, (B), Miller St., Ludlow, Mass.
Malcolm, Vincent T., (B), 151 Oak St., Indian Orchard, Mass.
Sproat, Andrew T., (B), 144 Pasco Rd., Indian Orchard, Mass.
Tefs, Edwin O., (B), 184 Bowles Park Extension, Springfield, Mass.

WICHITA

Vogt, Roy M., (C), 2815 E. 13th, Wichita 6, Kan.

YORK-CENTRAL PENNA.

Sedam, Marvin G., (B), Alloy Rods Co., 501 E. Prospect St., York, Pa.

NOT IN SECTIONS

Becerra, Clefas, (C), 34 Quintana Bros., Navojoa Son, Mexico.
Boyer, Charles V., (B), 2618 Auburn St., Erie, Pa.
Brand, Frederik J., (B), 121 Wellsway, Bath Somerset, England.
Brent, Charles W., (B), Casper Branch, 137 N. Center St., Casper, Wyo.
Brown, Edwin J., (C), 250 W. 22nd St., Erie, Pa.
Couch, M. E., (C), U.S.S. *Black Hawk*, c/o Fleet Post Office, San Francisco, Calif.
Daniels, George G., (C), 24 Jubilee Rd., Portchester, Fareham Hants, England.
Gilkeson, Harlon H., (C), Millport, N. Y.
Grabosky, Stanley M., Sgt., (C), F.A.-R.T.C., Fort Bragg, N. C.
Lakner, Robert, (B), The National Radio & Engrg. Co., Ewart House, 22 Bruce St., Bombay, India.
Lardge, Howard E., (B), 378 Rossendale Rd., Burnley, Lancs., England.
Phillips, Paul Barringer, (C), The Guiberson Corp., 2625 Elm St., Dallas, Tex.

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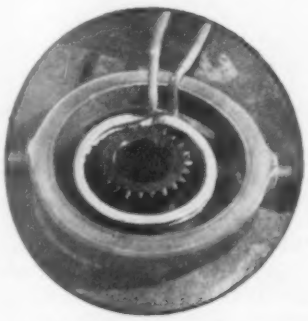

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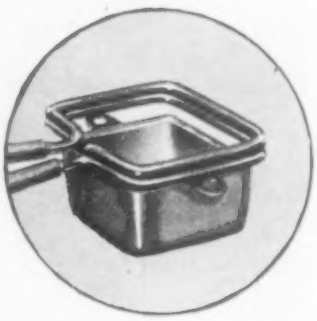

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Shea, Jack (from C to B), Columbian Steel Tank Co., 1509 W. 12th St., Kansas City 7, Mo.

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SECRETARY-TREASURER—W. L. POOLE, Air Reduction Sales Co., 2825 N. 29th Ave., Birmingham, Ala.

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SECRETARY—W. P. BOLEN, 1303 Dartmouth St., Brunswick, Ga.

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SECRETARY—JAMES G. MURRAY, Panama Canal, P. O. Box 623, Diablo Heights, Canal Zone

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